Considering the effects of the Byzantine–Islamic transition: Umayyad glass tesserae and vessels from the qasr of Khirbet al-Mafjar (Jericho, Palestine)

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Abstract:	The paper reports and discusses data obtained by archaeological and archaeometric studies of glass vessels and tesserae from the qasr of Khirbet al-Mafjar (near Jericho, Palestine). Archaeological contextualisation of the site and chrono-typological study of glass vessels were associated to EPMA and LA-ICP-MS analyses, performed to characterise the composition of the glassy matrix (major and minor components as well as trace elements). Analyses allowed achieving meaningful and intriguing results, which gain insights into the production and consumption of glass vessels and tesserae in the near East during the Umayyad period (7-8th centuries). Within the analysed samples, both an Egyptian and a Levantine manufacture have been identified: such data provide evidence of a double supply of glass from Egypt and the Syro-Palestinian coast in the Umayyad period occurring not only in the glassware manufacture, but also in the production of base glass intended to be used in the manufacture of mosaic tesserae. Thus, the achieved results represent the first material evidence of a non-univocal gathering of glass tesserae from Byzantium and the Byzantines in the manufacture of early Islamic mosaics.
Response to Reviewers:	see attachment

Dear Editor,

please find enclosed the revised version of the manuscript titled: Considering the effects of the Byzantine-Islamic transition: Umayyad glass tesserae and vessels from the *qasr* of Khirbet al-Mafjar (Jericho, Palestine).

All the reviewers' suggestions are commented below and/or corrected in the revised version of the manuscript.

We hope that now our paper will be suitable for publication.

We are very grateful to the reviewers and to the editor for the useful comments which will improve our paper.

Best regards

Mariangela Vandini

Ravenna, 25th February 2017

Mariangela Vandini

<u>Reviewer #1</u>

The majority of suggestions and comments of Reviewer #1 were considered and text modified accordingly.

A few exceptions are commented in detail.

Major changes are directly reported in the manuscript by using red characters (please note: lines numbers referring to the revised version - in bold – and to the original submitted manuscript are reported).

Abstract

24-25 (were 26-27): a clarifying sentence was inserted. Authors are aware that the manufacture of artefacts and tesserae occurred in secondary workshops, often located far away from the primary workshops where the base glass was produced.

Introduction

45-74 (were 49-52): this section was reviewed and improved as requested, relevant references were added.

90-92 (was 71): previously omitted early Islamic sites indicated in Neri et al. 2016 are now properly indicated in the text. Concerning data from Neri et al. 2017 (Kilise Tepe), the paper was not cited in the manuscript as it was published after its submission to JAAS. This reference is now quoted when Levantine tesserae are discussed (line 440).

On the other hand, authors are not able to access the forthcoming paper by Verità et al. Scientific investigation of glass tesserae from the 8th century AD archaeological site of Qusayr Amra (Jordan) as the book "The colours of the Prince" has not been published yet by ISCR.

113-114 (was 90): "old style" has been replaced with "not stratigraphic"

113-129 (were 90-105): authors do not mention cullets, but tesserae and vessel fragments. The discussion concerns a consumption site and no evidence for a secondary workshop has been discovered. It is not possible to know if the tesserae originally belonged to a wall or floor decoration because no decoration is preserved. The authors are aware that the chronology of the materials found in a layer of the second phase could be a controversial issue but this does not necessarily imply they were used and produced before. The chrono-typological and archaeometric study reported in the following parts of the paper add data to aid the interpretation.

Fig. 1a. Figure was changed

Fig. 1b. Figure provided in grayscale.

Materials and methods

131-171 (were 116-134): in the authors' opinion, the aim of the *Introduction* of the paper is to contextualize the study and introduce the material selection. We are aware that the *Materials* section is, generally, a list of objects and samples whereas, in this case, it represent a chrono-typological study of the analysed materials. For this reason, we prefer to keep the section of material description separated from the *Introduction* and a re-naming of sections was proposed by introducing Section *2. Chrono-typology of glass findings* and naming the following section *3. Experimental*

Typologies and comparisons were revised according to reviewer's comments and suggested references.

Tab. 2a,b: authors would prefer to keep tables in the text.

A6 tessera can be better defined as "weak turquoise", as authors agree that "pale blue" could be confusing.

A15 is not a cobalt-coloured blue tessera. Authors believe it could be better described as "weak turquoise" rather than "pale blue" so as to avoid misunderstanding.

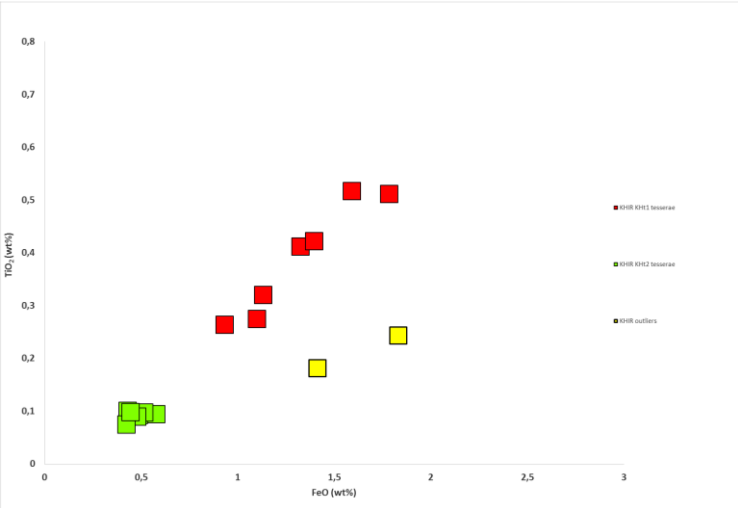
168 (was 141): there are no indication about Am12 and Am14 being gold leaf tesserae. Only Am/Au11 is a gold leaf one, that lost cartellina and shows traces of the gold leaf on one side.

184-205 (were 158 and 160): standard deviation and accuracy are now provided. Standard materials used as references are indicated in the text, in the Experimental section. Text was changed and requested information added.
Ten measurements were performed to test homogeneity, because we are also analysing opaque coloured tesserae. As inserted in the revised version (lines 94-96), an in-depth characterisation of colourants and opacifiers used in the secondary manufacture of the tesserae is currently being carried out, by means of a multi-analytical approach (VIS-RS, OM, SEM-EDS, micro-Raman), and not reported here.

Results

Tab.2 and **Tab.3** have been improved according to the requests.

216-218 (were 185-188): in the Egypt I opaque tesserae, FeO is always correlated to TiO2 (see the scatter plot reported below) and it was not subtracted; concerning the Levantine tesserae, the only samples not displaying a correlation between FeO and TiO2 are Am12 (translucent weak brown) and A15 (translucent weak turquoise). However, following a homogeneity criteria, we propose to maintain the choice of non-subtracting FeO, after having checked that the effect on data and discussion for the two samples is negligible.



TiO2 vs FeO

223-226 (were 192-194): we agree that, in the case of A15 tessera, the higher MgO, K2O, and P2O5 contents could also indicate a recycling process and, consequently, we took this interpretation into account. Authors would prefer to keep this sentence in the original position, because it is linked to the previous one.

Were 195-197: these lines have been deleted as requested.

231-267 (were 199-236): The opinion of the authors is that the results concerning the glassy matrices of vessels and tesserae need to be separated because different compositional categories were identified (Egypt I, Apollonia-type and Bet Eli'ezer-type for the tesserae; Egypt II, Apollonia-type and Bet Eli'ezer-type for the vessels). The reason for discussing trace element data before major oxides primarily stems from the fact that trace element patterns and REE distributions allow to precisely define the type of sand employed in the manufacture of the base glass, providing a precise indication on the provenance of the raw materials. This approach in discussing data has recently been proposed by Phelps at al. 2016 and authors believe it could be incisive also in this case.

Figure 4a: four samples are shown because, as specified in the text and in the caption of the figure itself, LA-ICP-MS did not provide useful data for samples KH02 and KH07.

Discussion

Authors are aware that the discussion of the achieved data is quite complicated. Instead of rewriting the whole section, we would like to propose some changes to the original text according to the reviewer's comment. Figures were changed and improved.

317: authors accept the reviewer's comment and suggest to remove this topic.

342-360 (were 368-376): text was improved, with the opinion that this paragraph is useful to valorise the achieved data concerning this peculiar set of tesserae, belonging to the Egypt I category.

388-446 (were 404-459): authors do not state that the raw glass necessarily indicate the production area of the tesserae, but of the raw materials employed in the base glass manufacture.

436-446 (were 452-453): authors are aware that in the quoted references Levantine compositional categories also occur with others; changes were made in the text to make this statement clearer.

444 (was 459): authors apologise for having also quoted the study case of Sagalassos. The quote has now been removed from the text.

447-460 (were 462-474): text was rewritten according to the reviewer's comments.

Conclusions

As requested, conclusions have been reviewed.

Reviewer #2

All the reviewer's suggestions are accepted and reported in the revised version of the manuscript.

Introduction was improved and the still open questions discussed more thoroughly.

VIS-RS data were removed. Actually, the entire part on colourants and opacifiers was removed since preliminary data were improperly presented. Authors agree with the reviewer that data on colour and opacity should be discussed in depth. Therefore, an in-depth characterisation of colourants and opacifiers used in the secondary manufacture of the tesserae is currently being carried out, by means of a multi-analytical approach (VIS-RS, OM, SEM-EDS, micro-Raman), and is not reported here (see revised version lines 94-96).

Figures were improved as suggested and references added when requested.

In paragraph 4.1, the discussion on natron shortage was removed since this issue requires further in-depth analysis.

Changes are directly reported in the manuscript by using blue characters.

Considering the effects of the Byzantine-Islamic transition: Umayyad glass tesserae and vessels from the *qasr* of Khirbet al-Mafjar (Jericho, Palestine)

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Abstract

The paper reports and discusses data obtained by archaeological and archaeometric studies of glass vessels and tesserae from the *qasr* of Khirbet al-Mafjar (near Jericho, Palestine). Archaeological contextualisation of the site and chrono-typological study of glass vessels were associated to EPMA and LA-ICP-MS analyses, performed to characterise the composition of the glassy matrix (major and minor components as well as trace elements). Analyses allowed achieving meaningful and intriguing results, which gain insights into the production and consumption of glass vessels and tesserae in the near East during the Umayyad period (7-8th centuries). Within the analysed samples, both an Egyptian and a Levantine manufacture have been identified: such data provide evidence of a double supply of glass from Egypt and the Syro-Palestinian coast in the Umayyad period occurring not only in the glassware manufacture, but also in the production of base glass intended to be used in the manufacture of mosaic tesserae. Thus, the achieved results represent the first material evidence of a non-exclusive gathering of glass tesserae from Byzantium and the Byzantines in the manufacture of early Islamic mosaics.

Keywords

Umayyad glass vessels/tesserae
Byzantine-Islamic transition
Early Islamic period
EPMA
LA-ICP-MS

1. Introduction

Research over the last decades has led to the emergence of quite a colourful and complex picture concerning manufacture and supply of early Islamic glass (7th – early 9th centuries) in the Near East. Previous studies have demonstrated that a remarkable change in glass technology started occurring at the beginning of the 9th century (or slightly earlier) in the Near East, when plant ash was reintroduced as main fluxing agent in substitution to natron and the production of glass objects with distinctive Islamic features began (Henderson 2002; Whitehouse 2002; Henderson et al. 2004; Shortland et al. 2006; Henderson 2013). Prior to this change, the glass industry of 7th and 8th centuries had been strongly influenced by both Sasanian and Roman-Byzantine traditions (Carboni 2001; Carboni and Whitehouse 2001; Tait 2012; Henderson 2013). Sasanian influence over early Islamic glass production is clearly visible, for instance, in the so-called facet-cut bowls, a kind of decoration the Sasanian glasshouses excelled in (Brill 1999; Mirti et al. 2008; Tait 2012; Henderson 2013; Simpson 2014). The other main influence may come from the Romans and the Byzantines, regarded as masters of glass technology. The use of earlier Roman glass techniques and traditions, like mosaic glass tileworks, the intricate animal-shaped "cage flasks" and the sandwiched gold-glass, has indeed been largely attested (Tait 2012). However, the need to introduce new traditions can be recognizable in the early experimentation of both new forms, like the so-called "dromedary flasks" or the mallet- and bell-shaped flasks, and decoration, as pincered glasses and the re-elaborated version of the Roman "gold-glass" (Tait 2012; Whitehouse 2012).

A pivotal issue to be investigated is the current relationship between early Islamic and Byzantine mosaic manufacture and technology, with specific reference to both craftsmen and tesserae supply. At the dawn the Umayyad caliphate, the relations with the Byzantines were ruled by both attraction and opposition; besides, it is known that the most noticeable legacy of the Byzantine imperial heritage is the Umayyad policy of erecting imperial religious monuments. Muslim literary sources, like the 10th century *Chronicle* of al-Tabarī, the *History of Medina*, composed in 814 AD by the scholar Ibn Zabāla, and the 10th century *The best divisions for knowledge of the regions* by the geographer al-Maqdisī, claim that Umayyad caliphs requested and got from the King of the Greeks both workmen and mosaic cubes in order to construct an decorate religious buildings, like the Prophet's Mosque at Medina and the Great Mosque of Damascus (Gibb 1958). Also, tesserae at the Great Mosque in Còrdoba, are likely to come from Byzantium too (James 2006).

Nevertheless, the issue of the sent tesserae has arisen several problems due to the reliability - as well as the interpretation - of the sources themselves: should these texts be read as propaganda pieces aimed at enlightening the power of the Muslim rulers or, on the contrary, could they imply that the trade between Muslims and Byzantines went on despite their rivalry? (Gibb 1958; Cutler 2001; James 2006). Answers to these questions still need to be provided. Besides, in 1927-1928 after deep investigations about the Dome of the Rock in Jerusalem, Marguerite Gautier-Van Berckem came to the conclusion to be in front of "an autochthonous work of art, not executed by mosaicists from Byzantium, but by Syrian artists" (Gautier-Van Berckem 1969); later, she made the same assertion about the original mosaics of the Great Mosque of Damascus.

A recently published paper by Phelps and co-workers (Phelps et al. 2016) has given a fundamental contribution to the examination of the so-called Byzantine-Islamic transition, addressing to the issue of typo-chronological distribution and chemical characterisation of glass production groups during the 7-9th centuries. As regards the Umayyad period, research has showed a break with the Byzantine glass technology between the late 7th – early 8th centuries, which brought to recipe changes: a contraction in the Levantine glass industry, an import of Egyptian glass and the first (re)-appearance of plant ash technology.

Thus, even though Umayyad glass vessels are particularly under-represented in literature, existing research has outlined quite a heterogeneous scenario to deal with, providing clear evidence for glass production occurring both in Egypt and in Syria-Palestine region, as well as the use of a variety of chemical compositions Furthermore, when considering mosaic glass tesserae, the state of the art still remains obscure, since no scientific analyses are recorded in literature regarding Umayyad mosaic tesserae dealing with the composition of the glassy matrix, the raw materials provenance and the study of colourants and opacifiers. The only existing information concerning early Islamic mosaic glass tesserae are reported in a recent paper dealing with the study of the gilding technique of 4th-12th centuries Levantine tesserae: among other assemblages dating back to the late Byzantine period, it also includes a set of 11 samples from the Great Mosque of Damascus (8th century) and 5 tesserae from the 8th century Baths of Qsayr Amra (Neri et al. 2016).

The present paper reports and discusses base glass compositional data about naturally coloured glass vessels and *tesserae* from the *qasr* of Khirbet al-Mafjar. An in-depth characterisation of colourants and opacifiers used in the secondary manufacture of the tesserae is currently being carried out, by means of a multi-analytical approach, not reported here.

Also known as Hisham's Palace, by the name of the Umayyad caliph who ordered its construction in the first half of the 8th century, the *qasr* of Khirbet al-Mafjar is an amazing example of Desert Castles, winter residences of the Islamic caliphs. Located in the plain of Jericho (3.5 km north of the city - Fig. 1a), it is considered to be one of the most significant archaeological evidence of the early Islamic period in Palestine (Whitcomb and Taha 2013).

Archaeological research has demonstrated that the *qasr* went through different phases of construction and occupation. It was built between 736 and 746 AD and in 747/748 an earthquake seriously damaged the site without interrupting its occupation. The Palace's major period of occupation was during the Abbasid caliphate (ca. from 800 until 950 AD), when new buildings were constructed and added to the pre-existent structures (Grabar 1955; Grabar 1963; Whitcomb 1988; Grabar 1993; Cirelli and Zagari 2000; Hattstein and Delius 2001; Whitcomb and Taha 2013). Firstly excavated between 1934 and 1948 and again in the 1960's (Grabar 1955; Whitcomb 1988; Hawari 2010; Whitcomb and Taha 2013), the *quasr* has recently been the focus of the *Jericho Mafjar Project*[1] (Hawari 2010; Whitcomb 2013; Whitcomb 2014).

During the 2011 season, glass vessels and tesserae were found inside the so-called Original Residence or Northern Building, completely excavated by Awni Dajani (under Jordanian authority) at the beginning of the 1960s, but there are no published records and no reports of the massive not stratigraphic excavation have been found up to now. Thanks to recent analyses and surveys on the structures and some trenches within small parts of the site (not previously investigated), a new drawing of the building has been provided (Fig.1b), with a wider comprehension of the phasing. According to archaeological evidence, it can now be stated that the Original Residence was contemporaneous with a Grape Press for wine production, recently discovered and early Umayyad in date. Moreover, during the last research seasons, it also emerged that this phase was probably connected to a wider building, identified by remote sensing investigations that highlighted several differently orientated hidden structures, in a middle area between the palatial complex and the northern building. The central area of the new building was never excavated and it is probably connected to an earlier period of occupation, dating back to the Late Roman (end of the 7th century) or early Umayyad (7th – 8th century), possibly belonging to the period of Sulayman ibn Abd al-Malik (715-717 AD). The mosaic tesserae and the other glass fragments belong to a second phase, dated to the Hisham's caliphate (724-743 AD), and they were connected to the court of the Northern Building, soon after the abandon of the large agricultural estate. Moreover, the Northern Building was abandoned after having been damaged by the earthquake, and, consequently, the findings can be confidently ascribed to the period between 724-748\9 AD (Whitcomb 2013).

2. Chrono-typology of glass findings

A set of 21 fragments of naturally coloured glass vessels and 16 mosaic glass tesserae was collected from the northern side of the Northern Building. Among the whole set of vessels, 7 fragments were selected to be investigated through a multi-analytical approach. This selection was made on the basis

[1] A detailed overview of the Project and its results is provided at www.jerichomafjarproject.org.

of archaeological and chrono-typological criteria, by preferably choosing the samples referable to documented or recognisable forms. About the tesserae, the whole set of available samples was investigated, due to the variety of the different colours and degrees of opacity.

Concerning the recovered vessels, 2 rims, 2 bottoms, 1 handle and 2 fragments of decorated walls were selected to be analysed. All of them were accurately micro-sampled, to preserve the integrity of the profile. The identified forms are summarised in Table 1.a and sketched in Fig. 2. Among the most interesting selected finds is a loop handle with a slightly pinched thumb-rest, preserved as two contiguous fragments (KH01) made of weak green glass. Attributable to a cup, or a cup-shaped oil lamp, the handle has different possible comparisons in the Islamic world, with or without the thumb-rest, generally dated to the Umayyad period (Gorin-Rosen and Katsnelson 2005; Gorin-Rosen and Katsnelson 2007; Gorin-Rosen 2008; Gorin-Rosen 2010). However, the closest similarity is shown with an handle found at Bet Shean (or Bet She'an – Israel), recovered under the debris of the 749 AD earthquake from the *sūq* of Hishām (Hadad 2005). Datable back to Late Byzantine-Umayyad period is a small neck with an infolded rim, made of weak turquoise glass (KH05). Fragment KH04 is consistent in a straight rim with wall folded towards the inside, quite common in the glass productions of Byzantine and Umayyad period; this fragment can be referred to a small bottle made of weak olive green glass (Dussart 1998; Hadad 2005). Find KH06 is a slightly concave base of weak turquoise glass, resembling those documented in archaeological contexts dated from the Late Byzantine-Umayyad period onwards and often occurring as a reproduction of earlier typologies (Katsnelson 1999; Foy 2012). KH02 and KH03 are two fragment of weak green-coloured walls, showing traces of a trailed decoration made in the same colour of the body, probably referable to a bifurcated ribs decoration. This kind of decorative motif, showing either vertical or horizontal orientation, is frequently attested from the Roman to the Umayyad period, documented for different typologies of vessels (Harden 1936; Crowfoot 1957; Clairmont 1963; Barag 1978; Weinberg and Goldstein 1988; Dussart 1998; Gorin-Rosen 2006; Gorin-Rosen and Katsnelson 2007; Antonaras 2010). The set also includes a small fragment of the central part of a base, made of weak turquoise glass (KH07). The find resembles a concave base of bottle identified by Hadad in the *sūq* of Hishām and dated to the Umayyad period (Hadad 2005); however, the small dimensions of fragment KH07 do not allow a certain identification of the original typology.

Among the tesserae, a set of 16 coloured samples (11 opaque and 5 translucent) was selected (Table 1.b). The opaque sub-group comprises 4 tesserae in various shades of green (Vsr4, V5, Vc8, Vc9), 3 in different tones of weak turquoise (A6, A7, A7 bis), 1 of a deep red glass (R1), 1 of a greenish-yellow glass (G/V3), 1 of a yellow glass (G2), and 1 of a greyish pale blue glass (Ga10). The transparent sub-group is formed by: 2 tesserae of brown glass (Am14, Am12), 1 of brown glass with golden leaf (Am/Au11), 1 of a weak turquoise glass (A15) and 1 of greenish-yellow glass (G/V13).

3. Experimental

All samples were preliminary cleaned by using demineralized water and dentist tools, softly scraping the surfaces to remove remains of soil and dirt.

An Olympus S761 stereomicroscope (magnification up to 45x) associated with an Olympus Soft Imaging Solutions GMBH model SC100 camera was used for a preliminary morphological observations and documentation.

A NCS (Natural Colour System) chart was used to provide a preliminary objective definition of the colour of the tesserae.

Polished sections were prepared by embedding samples in a polyester resin. After polishing, sections were carbon-coated to perform Electron Probe Micro-Analysis (EPMA). EPMA analyses were carried out to determine the bulk chemistry of all samples. The chemical analyses of major and minor elements (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P, S, Cl, Cr, Co, Cu, Sn, Sb, and Pb) were performed using a Cameca SX 50 microprobe equipped with four scanning wavelength-dispersive spectrometers (WDS). A beam current of 20nA and an acceleration voltage of 20KV were used. The reference Smithsonian glass A standard (Jarosewich 2002) was employed as primary reference sample. Ten points were analysed on each sample and the mean value was calculated. The measured accuracy for the analysed elements was better than 3%. The standard deviations among the analysed points resulted to be between 1-3 and 3-5% for major and minor constituents, respectively, showing a good homogeneity in the main constituents. The detection limit for the minor elements was between 0.01 and 0.04 wt%. The correction program is based on the PAP method (Pouchou and Pichoir 1988) and was used to process the results for matrix effects.

LA-ICP-MS was carried out to determine the concentration of 37 trace elements. The analyses were performed by a Thermo Fisher X- SeriesII quadrupole based ICP-MS coupled with a New Wave ablation system with a frequency quintupled (λ=213 nm) Nd:YAG laser. The laser repetition rate and laser energy density on the sample surface were fixed at 20 Hz and ~18 J/cm2, respectively. The analyses were carried out using a laser spot diameter of 100µm on the same polished samples used for EPMA, after carbon coating removal. External calibration was performed using NIST SRM 610 and 614 glass as external standard, and 29Si, previously determined by EPMA, as internal standard, following the method proposed by Longerich et al. (Longerich et al. 1996). Six points were analysed on each sample to test homogeneity and the mean value was calculated. The standard deviations among the acquired points on the same sample were below 10% for all the elements, with the exclusion of Cu, Sn and Pb with more variable SD. Standard Reference Material NIST612 (Pearce et al. 1997) was used as a secondary reference sample to check precision and accuracy. The distribution of REE and of the other trace elements was analysed by normalizing the data to the upper continental crust (Wedepohl 1995).

4. Results

The composition of the major and minor elements, obtained by EPMA, is reported in Table 2a and LA-ICP-MS chemical data for trace elements are shown in Table 3.

In order to compare the base glass composition of the opaque tesserae with the categories reported in literature for naturally coloured glass, compositional data were recalculated to minimise any effect caused by elements intentionally added as colourants/decolourants and/or opacifiers. The reduced composition was obtained by subtracting the oxides of the elements probably due to additives, and by normalising to 100 the remaining data (Table 2b). In particular, the subtracted oxides were CuO, SnO_2 and PbO. Sb_2O_3 and CoO were not subtracted since their values are negligible (below 0.01 wt%). FeO and TiO_2 were not subtracted when calculating the reduced composition (even though the presence of iron may be due to an intentional addition) since these elements are typically found as sand contaminants related to heavy minerals. For the opaque tesserae, the following discussion is based on reduced compositional data.

The analysed samples are all of natron type glass, being MgO and K2O contents below 1.5 wt%, (Fig. 3) (Lyliquist and Brill 1993). The pale blue tessera A15 is the only one showing higher MgO and K_2O (respectively 2.23 wt% and 1.68 wt%), even though below the value of 2.5 wt%, unequivocally referable to the use of plant ash as flux (Lyliquist and Brill 1993). The higher MgO (2.23 wt%) and K_2O (1.67 wt%) contents, together with the higher P_2O_5 (0.38 wt%), could indicate either the occurrence of a contamination during the production process (Paynter 2008), or the melting of soda plant-ash mixed with silica (Neri et al. 2016).

4.1 Vessels

Trace element patterns (Fig. 4a,b) show that KH01, KH03 and KH05 exhibit lower strontium (146.85 – 209.20 ppm), higher zirconium (129.05 – 258.40 ppm) and a less depleted REE pattern, relative to continental crust. Considerable quantities of titanium (0.27 – 0.33 wt%) and iron oxides (0.81 – 0.91 wt%) can also be observed (Table 2a). Contrariwise, KH04 and KH06 are characterised by higher Sr contents (305.47 – 321.93 ppm) together with relatively lower Zr amounts (35.30 – 63.95 ppm); higher alumina and higher depletion of REE (particularly heavy REE) can also be noticed when compared to KH01, KH03 and KH05. Due to scarcity of material, no LA-ICP-MS data are available for sample KH02 and KH07; therefore, they are only discussed according to their major and minor oxides values.

From now on, the first group of vessel samples (KH01, KH03, KH05 – and KH02) will be referred to as KHv1, whilst the second group (KH04, KH06 – and KH07) will be named KHv2.

CaO/Al_2O_3:Na_2O/SiO_2, TiO_2/Al_2O_3:Al_2O_3/SiO_2 and FeO/TiO_2:FeO/Al_2O_3 bi-plots (Fig.5-7) further enhance the distinctive features showed by the samples under study: KHv1 vessels have higher CaO/Al_2O_3 than KHv2, whilst Na_2O/SiO_2 does not show significant shifts; KHv1 vessels also show consistently higher TiO_2/Al_2O_3 and FeO/Al_2O_3 ratios when compared to KHv2 vessels.

Sample KH06 is characterised by lower Na_2O/SiO_2 and CaO/Al_2O_3 than the other KHv2 vessels. Vessel KH02 shows features comparable to KHv1 group, while the behaviour of KH07 is consistent with KH04.

4.2 Tesserae

Trace element patterns allow a first well-defined separation of the analysed tesserae in two main groups. R1, G/V3, Vsr4, V5, A6, Vc9 and Ga10, from now on referred to as KHt1, show lower strontium, higher zirconium and a less depletion of REE when compared to G2, A7, A7bis, Vc8, Am/Au11, G/V13 and Am14, from now on labelled KHt2 (Fig. 4c,d). KHt1 samples also display higher titanium and iron oxides contents, respectively ranging from 0.27 to 0.51 wt% and from 0.94 to 1.78 wt%.

KHt1 tesserae show lower lime (2.75 - 4.53 wt%) and higher alumina contents (3.35 - 4.26 wt%) when compared to KHt2 samples (lime ranging from 6.68 to 10.37 wt% and alumina ranging from 2.22 to 3.18 wt%); moreover, the two groups differ in terms of soda contents, KHt1 tesserae containing higher soda (16.29 – 18.74 wt%) with respect to KHt2 (12.09 – 15.68 wt%). The above differences are clearly displayed in CaO/Al_2O_3:Na_2O/SiO_2,TiO_2/Al_2O_3:Al_2O_3/SiO_2 and FeO/TiO_2:FeO/Al_2O_3 bi-plots (Fig.5-7), also highlighting a strong separation of Am/Au11 from the other KHt2 tesserae due to its lower CaO/Al_2O_3 and Na_2O/SiO_2 ratios.

Am12 and A15 translucent tesserae can be considered as outliers, since they show a less definite behaviour that cannot allow unequivocally including them into neither the KHt1 nor the KHt2 group, although they have some common features with KHt2 samples.

5. Discussion

5.1 KHv1 and KHt1: Egyptian vessels and tesserae

Vessels and tesserae belonging to groups KHv1 (KH01, KH02, KH03, KH05) and KHt1 (R1, G/V3, Vsr4, V5, A6, Vc9, Ga10) have been manufactured by using sands richer in the heavy accessory minerals, characterised by relatively high contents of iron oxide, titanium oxide and zirconium, as well as by a less depleted REE pattern (Fig. 4a-d). These values, as well as the high soda contents, are typical of Egyptian glasses (Foy et al. 2003; Nenna 2014; Phelps et al. 2016).

However, even though they are linked by an Egyptian origin, KHv1 and KHt1 are separate glass groups: KHv1 vessels are made of Egypt II glass, whilst KHt1 tesserae correspond to Egypt I compositional category (Bimson and Freestone 1987).

Initially detected in a secondary workshop at El-Ashmunein (Middle Egypt) (Bimson and Freestone 1987), Egypt II glass was also identified by Gratuze and Barrandon (Gratuze and Barrandon 1990) in a study concerning coin weights from Fustat (Egypt). Vessels dating back to the Abbassid period (mid 8th to the end of 9th/beginning of 10th century), were also found belonging to Egypt II group, referred to as Group 7 by Foy and co-workers (Foy et al. 2003). Egypt II compositional group was also detected by Kato and co-workers at Raya (Sinai peninsula): more precisely, they label this group as N2-b, with the majority of the analysed objects falling within it (Kato et al. 2009). The so-called Upper Group, found at the monastery of St. Aaron on Jabal Haurn (near Petra, Jordan), also comprises vessels belonging to Egyptian II category (Keller and Lindblom 2008; Greiff and Keller 2014); interestingly, several vessels belonging to this Upper Group could indicate a certain degree of recycling, in accordance with their compositional features (Greiff and Keller 2014). Group C recognised by Freestone et al. (Freestone et al. 2015), including vessels, chunks and moils recovered from an early Islamic secondary workshop at HaGolan Street (Khirbet al-Hadra, North-Eastern Tel Aviv), is also equivalent to Egypt II compositional category. In a recently published paper, Phelps and co-workers (Phelps et al. 2016) identified 57 samples made of Egypt II glass (Group N-3), belonging to the period of the so-called Byzantine-Islamic transition (7th-9th centuries) and recovered from several archaeological contexts in the Near East. Lastly, some 6th-7th century Byzantine glass weights from the British Museum and the Bibliothèque Nationale de France were also found matching the Egypt II compositional category (Schibille et al. 2016).

KHv1 vessels show high lime, low alumina, lower soda and a low Sr/CaO ratio (Fig. 5-8), suggesting that lime is derived from a limestone source (Freestone et al. 2003; Phelps et al. 2016). The CaO/Sr ratios reported in the literature for natron glass produced with limestone in Middle Egypt El-Ashmunein (Freestone et al. 2003) are, indeed, of circa 616. CaO/Sr ratios measured for raw materials were reported by Wedepohl and co-workers (Wedepohl et al. 2011) and follow the same trend observed for the glass: low ratios for the marine carbonates, like shells (CaO/Sr=212) and higher ratios for limestone (CaO/Sr=870). CaO/Sr ratios measured for KHv1 samples range from 450 to 690, compatible with the use of an inland sand source.

A comparison between compositional features and chrono-typological study of the analysed vessels needs to be addressed. Concerning KHv1 vessels, it should be noted that KH02 and KH03 are two wall fragments of weak green glass, showing a decorative motif with trails of the same colour of the body, frequently attested from Roman to Umayyad period; the weak green loop handle with pinched thumb-rest (KH01) and the weak turquoise small neck with infolded rim (KH05) show precise comparisons with some published materials and can be attributed to vessel types datable to the Umayyad period and, more precisely, to the 8th century (see materials section). Analyses have demonstrated that these vessels are made of Egypt II glass, perfectly consistent with the majority of produced and consumed glass vessels of 8th century falling within this compositional category in the Near East as attested in the literature (Kato et al. 2009; Greiff and Keller 2014; Freestone et al. 2015; Phelps et al. 2016).

The tesserae belonging to KHt1 group are made of Egypt I glass as they show lower lime, higher alumina and higher soda when compared to KHv1 vessels (Fig. 5-7). Contrarily from what observed for the KHv1 vessels, CaO/Sr ratios found for KHt1 tesserae have, on average, a value of 150. This value is consistent with the use of a shell-containing coastal sand, as recently also stated by Phelps and co-workers with regard to early Islamic Egypt I glasses (Phelps et al. 2016). Data of major and minor oxides and trace elements here reported indicate the use of different sands for the production of vessels and tesserae of Egyptian manufacture, in particular with reference to the distribution of REE: even though the two sample sets show the same relative patterns, a higher depletion of REE is observed for the KHv1 vessels, indicating the use of a purer sand.

To date, evidence for the production of Egypt I glass has been only covered for the Roman period, as exhaustive research on the primary workshops located at Wadi Natrun and in the Mareotid area, near Alexandria, have demonstrated (Nenna 2014, 2015). Nevertheless, several studies witness the consumption of Egypt I glass in the late Byzantine/early Islamic period, also stating its rare occurrence. Groups 8 and 9 identified by Foy and colleagues (Foy et al. 2003) include glass vessels dating to the Umayyad period (mid 7th-mid 8th centuries), the location of whose primary glass workshops is still unknown. Group 8, characterised by higher levels of iron, alumina and titanium, corresponds to Gratuze and Barrandon's 1B group, whilst Group 9, which may pre-date Group 8, corresponds to Gratuze and Barrandon's 1A group (Gratuze and Barrandon 1990). Glass belonging to 1A and 1B groups has also been labelled Egypt I by Freestone et al. (Freestone et al. 2000). By analysing a conspicuous assemblage of glass finds excavated from two well-dated archaeological layers (from the 8th and the 9th centuries) at Raya (Sinai), Kato and co-workers identified the N2-a2 type, a low lime – high alumina glass comparable to Egypt I compositional category (Kato et al. 2009; Kato et al. 2010). A recently published study on late antique vessels and window glass from Cyprus (Ceglia et al. 2015) also outlines the presence of some few samples matching the Egypt I compositional category. Finally, among 133 analysed vessels, well-contextualised from selected excavations in the Near East and ascribable to the 7-12th centuries, Phelps and co-workers (Phelps et al. 2016) only found two samples corresponding to Egypt I group (Group N4).

CaO/Al_2O_3:Na_2O/SiO_2 and TiO_2/Al_2O_3:Al_2O_3/SiO_2 bi-plots (Fig. 5-6) unambiguously show that KHt1 tesserae match Egypt I compositional category and, even more precisely, late antique/early Islamic Egypt I. Reference data reported in the scatter plots highlight, indeed, a strong differentiation between late antique/early Islamic Egypt I (Gratuze and Barrandon 1990; Foy et al. 2003; Kato et al. 2009; Phelps et al. 2016) and earlier Egypt I (Picon et al. 2008), clearly revisable in the compositional features. Late antique/early Islamic Egypt I glass show lower soda, higher silica, higher alumina and slightly higher lime compared to earlier Egypt I. These characteristics imply the use of different batch recipes and, presumably, different sands. LA-ICP-MS data from this study also support the hypothesis recently proposed by Phelps and colleagues (Phelps et al. 2016) about the use of an Egyptian shell-containing coastal sand in the manufacture of early Islamic Egypt I glass (Fig. 4,8).

Whilst the production and consumption of Egypt II glass has been frequently documented in the 8th century Umayyad glass industry, having found an assemblage of Egypt I type (low lime – high alumina) represents quite a significant finding. To date, research has underpinned indication of Egypt I compositional category only playing a marginal role in glass production and consumption in the Umayyad period: for instance, within more than 500 glassware fragments analysed from Raya (Kato et al. 2009), less than 5% accounts for N2-a2 type; another example is represented by the small number of Umayyad lamps and vessels remains from the monastery of St Aaron on Jabal Harun (near Petra, Jordan), datable to the mid 7th to the mid 8th centuries, corresponding to the Egypt I group (Greiff and Keller 2014).

Nevertheless, what makes this finding absolutely remarkable is the fact that we are discussing glass tesserae and not vessels: it is the first time that evidence is provided of the existence of an Egyptian manufacture for Umayyad glass tesserae.

5.2 KHv2 and KHt2: Levantine vessels and tesserae

Vessels and tesserae belonging to groups KHv2 (KH04, KH06, KH07) and KHt2 (G2, A7, A7bis, Vc8, Am/Au11, G/V13, Am14) have been manufactured by using sands low in the heavy accessory minerals, with small contents of iron oxide, titanium oxide and zirconium, and showing a greater REE depletion (Fig. 4a-d). In addition, the relatively high alumina suggests the use of a mature sand, and the positive correlation between high lime and high strontium indicates a coastal sand containing shells (Fig. 5, 8) (Freestone et al. 2003; Phelps et al. 2016).

As in the case of the Egyptian samples, even if they show a common Levantine origin, KHv2 and KHt2 are distinct glass groups.

The term *Levantine* has been generally used to describe two main compositional categories manufactured on the Syro-Palestinian coast, first identified by Freestone and co-workers (Freestone et al. 2000; Freestone et al. 2002). The first group, named Levantine I, includes 6th to 7th century glass from Apollonia-Arsuf, Bet She'an and Dor (Freestone et al. 2000; Freestone et al. 2008). Evidence suggests that the sand from the Belus delta in the Bay of Haifa (or similar coastal sands containing calcareous fragments) was used for the production of Levantine I glass (Freestone et al. 2003). This type of glass is similar to the Roman glass type (e.g. Foster and Jackson 2009), but differs in being slightly higher in lime (CaO around 8–9 wt%, as compared to 6.5–7.5 wt% in Roman glass) and alumina (Al_2O_3 of about 2.5–3 wt%, as compared to 2–2.5 wt%) (Freestone et al. 2000). The second group, named Levantine II, is associated with the primary furnaces found at Bet Eli'ezer, near Hadera (Israel), probably active between the 6th and the early 8th centuries (Freestone et al. 2002; Freestone et al. 2003). Levantine II glass is distinct from Levantine I and Roman glass for its lower lime and sodium and higher silica contents, indicating a different silica source than the one utilized for Levantine I glass, but still some local coastal sand (Freestone et al. 2002; Freestone et al. 2003).

Concerning the vessels, patterns elucidated on the basis of LA-ICP-MS data markedly distinguish KH04 and KH06 samples from the Egyptian set (Fig. 4a,b). The former are, indeed, characterised by very high strontium together with relatively lower zirconium, as well as by a higher depletion of REE (particularly light REE). Furthermore, KH04 and KH06 samples show a CaO/Sr ratio of 270 and 217, respectively; these values are comparable with those found by Freestone and co-workers (Freestone et al. 2003) for Bet Eli'Ezer and Bet She'an glasses and compatible with the use of a Levantine coastal sand. Glass of Levantine origin is, indeed, generally made by using pure sand, as confirmed by the low levels of all the analysed trace elements and by the strongly depleted REE patterns. Major oxides demonstrate that samples KH04 and KH07 seem to better correspond to Apollonia-type (Levantine I) glass, being characterised by high lime (7.70 – 8.71 wt%), high soda (14.29 – 15.06 wt%) and low silica (71.17 – 72.27 wt%) contents (Fig. 5-7). Whilst KH07 lacks of a precise typological identification, the light olive green fragment KH04 is referable to a straight rim with wall folded towards the outside, belonged to a small bottle probably similar to the n. 126 of the Bet Shean's catalogue, dated to the Umayyad period (Hadad 2005). Sample KH06 has lower lime (6.63 wt%), lower soda (12.89 wt%) and higher silica (75.44 wt%) contents, consistent with an attribution to Bet Eli'ezer-type (Levantine II) group (Fig. 4 and 7); this hypothesis is further enhanced by the chrono-typological data, since this fragment of a flat bottom, probably belonged to a globular bottle, is similar to some types documented in the catalogue of the glass findings from Al-Hadir (northern Syria) (Foy 2012), dated from the 8th century AD onwards, therefore of a slightly later time.

Concerning KHt2 tesserae, trace element patterns are consistent with their attribution to a Syro-Palestinian production, being characterized by high strontium and low zirconium contents: all these

Levantine samples exhibit a CaO/Sr ratio around 270 (with the only exception of Vc8, showing a slightly lower ratio); a strongly depleted REE pattern is also noticeable in comparison to the tesserae of Egyptian production (Fig. 4c,d). Major oxides soda, silica, lime and alumina (Fig. 5, 6) demonstrate that the majority of samples (opaque G2, A7, A7bis, Vc8 and translucent G/V13, Am14) show a close match with Apollonia-type glass. The only exception is represented by Am/Au11tessera, showing compositional features more similar to the ones of Bet Eli'ezer-type glass, being characterised by higher silica (74.32 wt%), lower soda (12.09 wt%), lower lime (6.68 wt%) and higher alumina (3.17 wt%) contents.

With regard to the Umayyad period (mid 7th – mid 8th century), several studies have attested the use of Levantine glass in the manufacture of vessels. Among the material from the site of Raya (Sinai), Kato and colleagues (Kato et al. 2009; Kato et al. 2010) have identified the so-called N1 type, corresponding to Levantine I and/or Levantine II, accounting for about 30% of the whole assemblage. In their study concerning glass vessels, chunks and moils from the early Islamic secondary workshop at HaGolan Street (Khirbet al-Hadra, Tel Aviv), Freestone and co-workers (Freestone et al. 2015) recognised two groups comparable with Levantine glass: Group B, more closely matching Bet Eli'ezer-type, and Group A, supposed being a different type of Levantine glass, previously unknown. Greiff and Keller (Greiff and Keller 2014) also highlighted the presence of Umayyad glassware in the monastery of St. Aaron belonging to both Apollonia- and Bet eli'ezer-type; additionally, authors emphasise the predominance of Bet eli'ezer-type glass in the Umayyad period compared to the small number of Egypt I finds. Concerning Umayyad Levantine glass, in a recently published paper Phelps and co-workers (Phelps et al., 2016) made quite an important assertion: while in the 7th century, Apollonia-type almost entirely dominated the production, from the early 8th the Bet Eli'Ezer-type started being mainly used, with the quantities of Apollonia-type glass falling dramatically.

Within the Levantine vessel fragments from Khirbet al-Mafjar, two samples (KH04 and KH07) are made of Apollonia-type glass and one sample (KH06) corresponds to Bet Eli'ezer-type. In accordance with data reported in the literature, both compositional categories are attested in the Umayyad period, and, more precisely, in the first half of the 8th century.

Concerning the mosaic tesserae, glass tesserae of a Levantine manufacture have been attested by several studies in a number of monuments dated from the 6th century onward, often together with other compositional categories. These include: the late antique church at Kilise Tepe, Turkey (Neri et al. 2017), the basilica of Hagia Sophia in Costantinopole, Turkey (Moropoulou et al. 2016); a number of basilicas in Ravenna, Italy, such as St Severo (Classe), St Apollinare in Classe, St Vitale and the Neonian Baptistery (Vandini et al. 2006; Verità 2010; Fiori 2015); the church of Hagios Polyeuktos at Saraçhane in Constantinople, Turkey (Schibille and McKenzie 2014); the chapel of St. Prosdocimus, inside the basilica of St Giustina in Padova, Italy (Silvestri et al. 2014); the Cross Church in Jerash, Jordan (Arinat et al. 2014) and the Petra Church, Jordan (Marii and Rehren 2009). Therefore, it would seem possible to link the use of a Levantine glass in the production of tesserae used in the decoration of Byzantine monuments.

If, to date, little is known about the manufacture of Byzantine mosaics (how raw materials were obtained by mosaicists? How was the supply of tesserae organised?), our knowledge of the Umayyad mosaics is even more restricted, especially in terms of materials and techniques. The presence of Levantine natron-based glass has been recently attested by Neri and co-workers (Neri et al. 2016) by analysing a set of 8th century gold leaf tesserae form the Great Mosque of Damascus and the Baths of Qusayr Amra.

Among the tesserae form the *qasr* of Khirbet al-Mafjar, six samples were found matching the Levantine I (Apollonia-type) compositional category and one is consistent with the Levantine II (Bet Eli'ezer group).

Having found some Levantine manufactured glass tesserae in an Umayyad mosaic could be interpreted as evidence of a kind of continuity with the Byzantine tradition and the gathering of materials from abandoned monuments cannot be excluded. On the other hand, the finds from Khirbet al-Mafjar include Egypt I tesserae too: since it is the first time this compositional category is attested for the manufacture of mosaic tesserae, from where should these glass come from?

6. Conclusions

The results from analysing glass from Khirbet al-Mafjar displayed remarkable outcomes regarding both the naturally coloured vessels and the tesserae. The obtained results enhanced the knowledge of glass provenance, manufacture and consumption in the Umayyad period (where currently very little is known), shedding, in particular, an entirely new light on the mosaic tesserae. Equally important compositional data can be framed in the broader view to improve the knowledge of the compositional categories identified in the literature, with particular reference to Egyptian manufacture in the late Byzantine/early Islamic period.

A captivating picture emerged for both vessels and tesserae as, in both cases, it was possible to distinguish between an Egyptian and a Levantine production.

Concerning the vessels, the presence of both an Egyptian and a Levantine manufacture with distinctive Umayyad features within an assemblage of samples confidently ascribable to the first half of the 8th century, perfectly matches that scenario of remarkable changes in the glass supply distinctive of the first half of the 8th century in Palestine clearly outlined by Phelps and colleagues (Phelps et al. 2016). The presence of Egyptian and Levantine glass, attested, to date, at both production (the secondary workshop at Tel Aviv quoted in Freestone et al. 2015) and consumption sites can be interpreted as a distinctive feature of the Umayyad period. The precise reasons of this occurrence are still an open question: are they linked to technological reasons as, for instance, the better working properties of Egypt II glass? Should this choice rather have been influenced by economic factors? Answers to these questions still need to be provided and further research is needed.

However, the most outstanding results of this study stem from the tesserae. For the first time a set of glass tesserae from an Umayyad mosaic has been investigated through an archaeometric approach, revealing highly significant new information. Within the analysed tesserae, both Egypt I and Levantine base glass have been, indeed, identified. Firstly, these data provide evidence of a double supply of raw glass from Egypt and the Syro-Palestinian coast occurring not only for glassware, but also for tesserae. In addition to that, it is the first time that the use of Egypt I compositional category is documented for mosaic glass tesserae. The comparison between early Islamic Egypt I and earlier Egypt I from Wadi Natrun seems, moreover, to show that these categories have dissimilar compositional features and, therefore, they could be interpreted as different groups.

Results from one set of tesserae cannot ultimately address the issue of understanding the actual relationship between early Islamic and Byzantine mosaic manufacture and technology. Nonetheless, data provide quite a thought-provoking starting point for further research, giving the first material evidence of a non-exclusive gathering of materials from Byzantium in the manufacture of early Islamic mosaics.

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Figure 1a

Click here to download Figure Figure 1.a.jpg

Figure 1b

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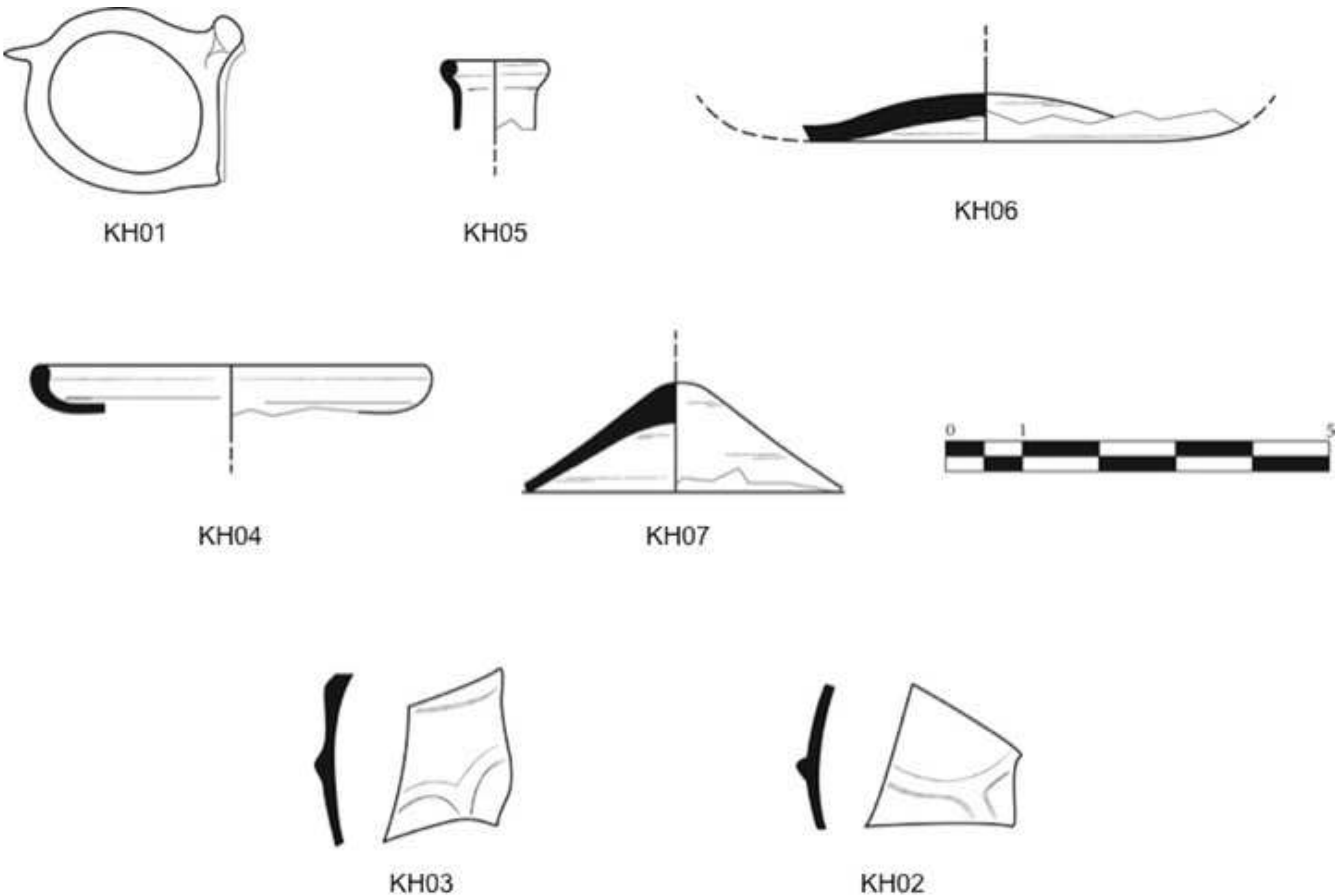
KH01
KH05
KH06
KH04
KH07
0
1
5
KH03
KH02

Figure 3

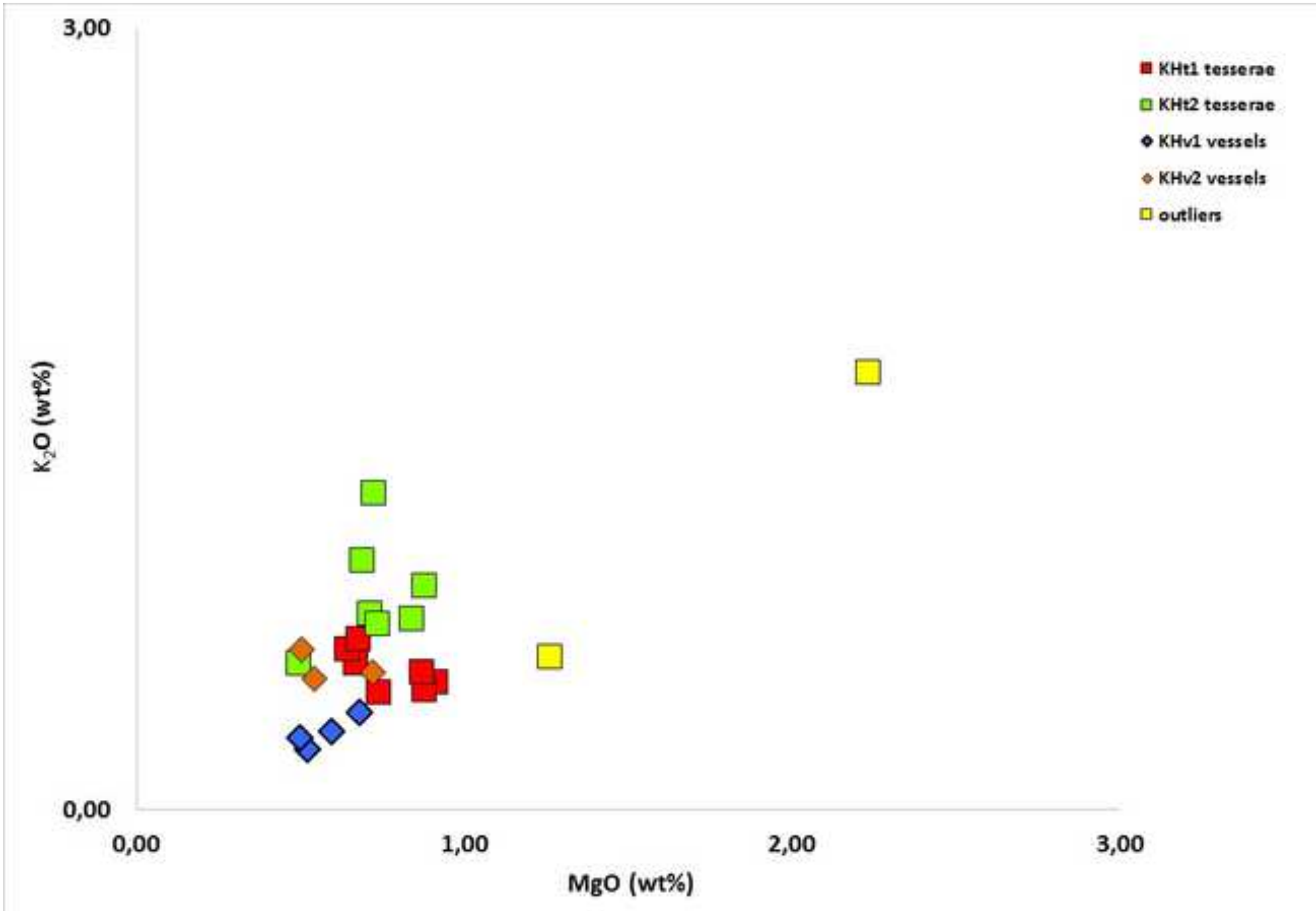
3,00
0,00
K2O (wt%)
0,00
1,00
2,00
3,00
MgO (wt%)
KHt1 tesserae
KHt2 tesserae
KHv1 vessels
KHv2 vessels
outliers

Figure 4a

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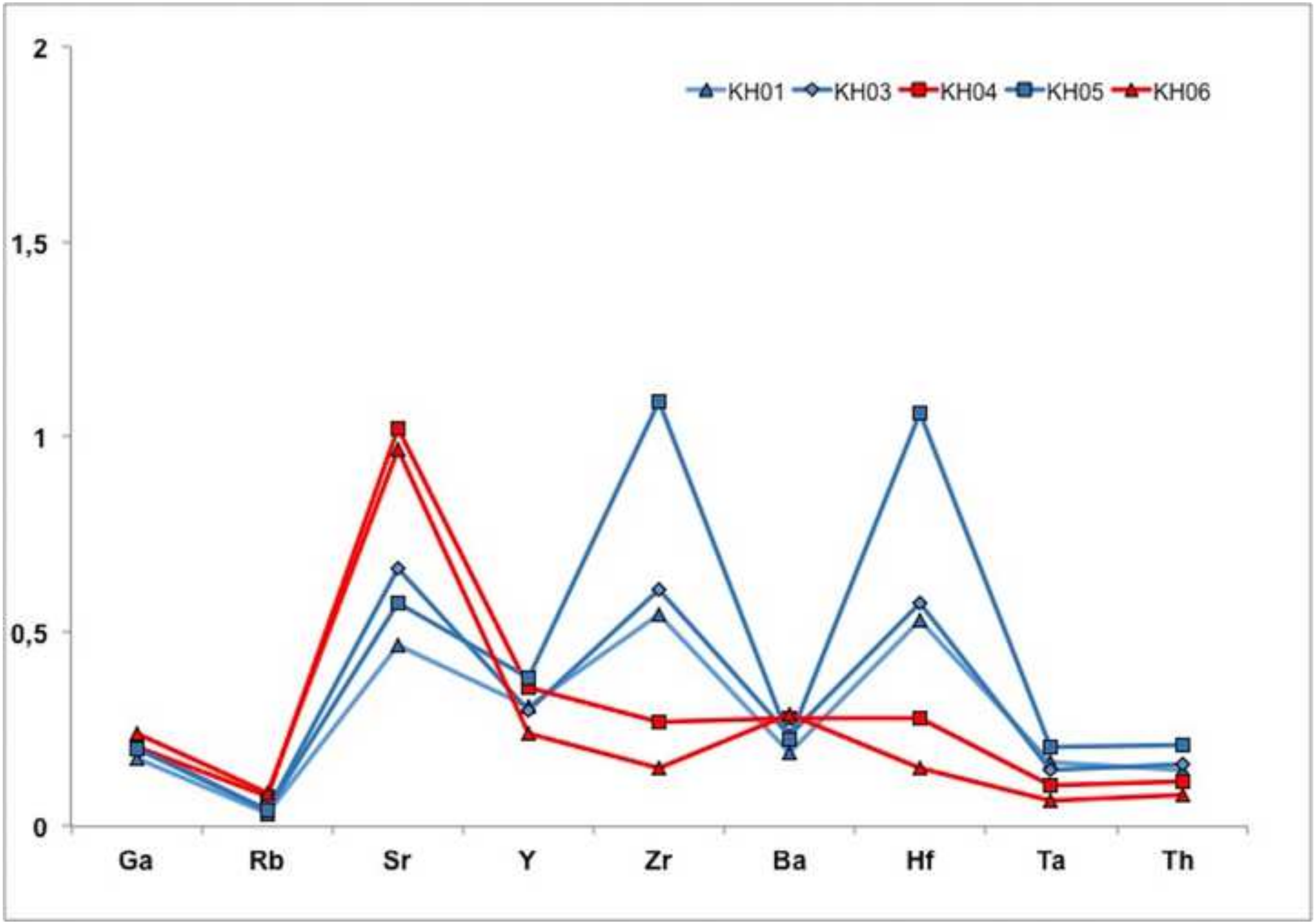

Figure 4b

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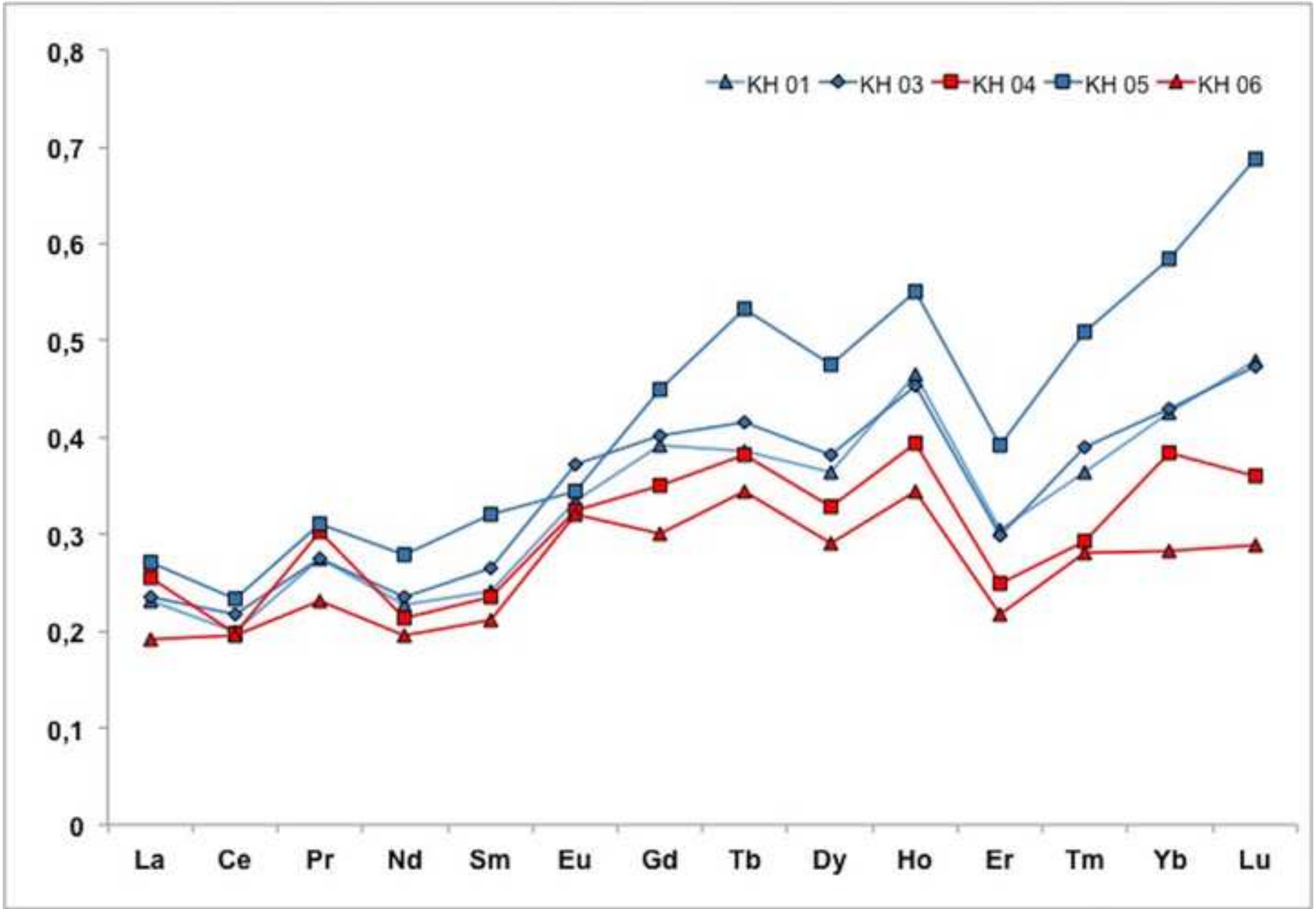

Figure 4c

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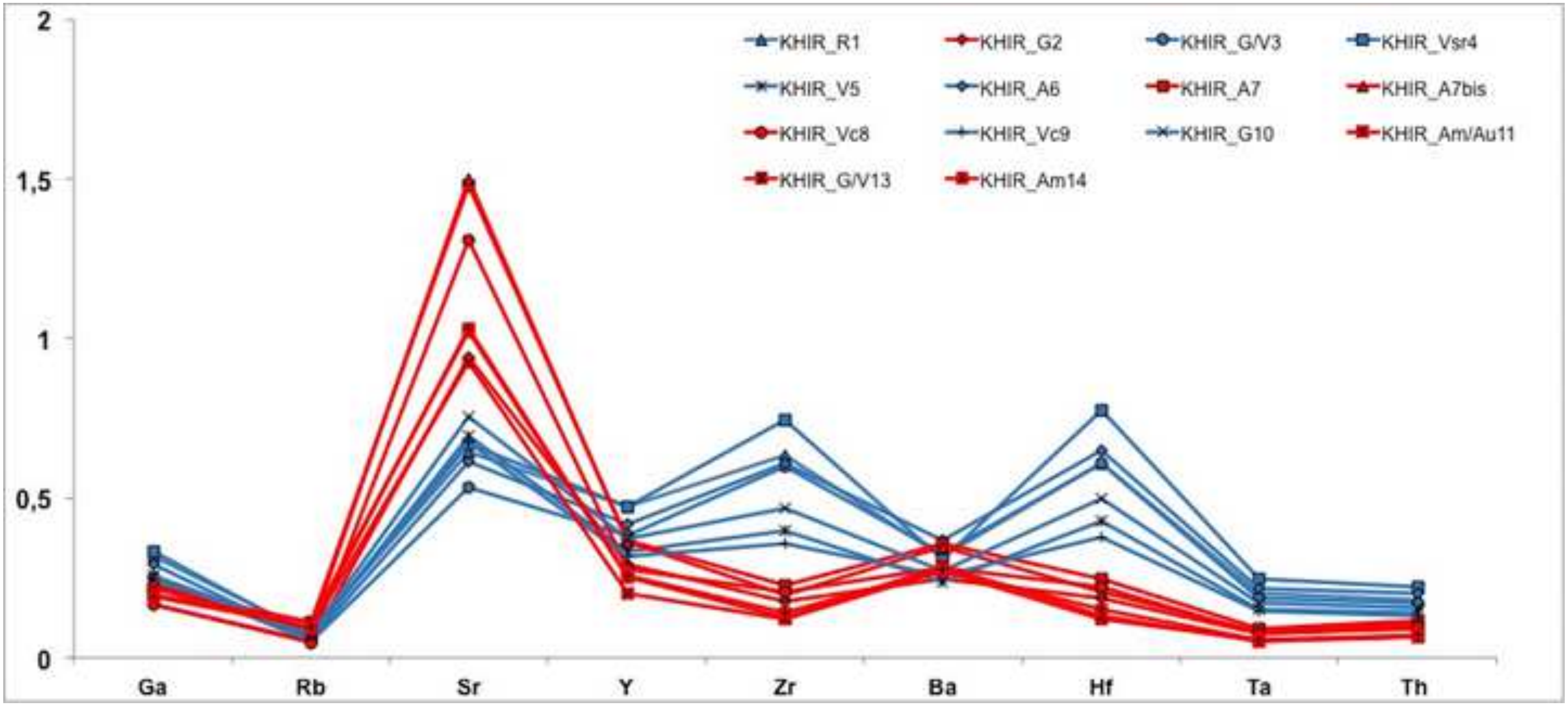

Figure 4d

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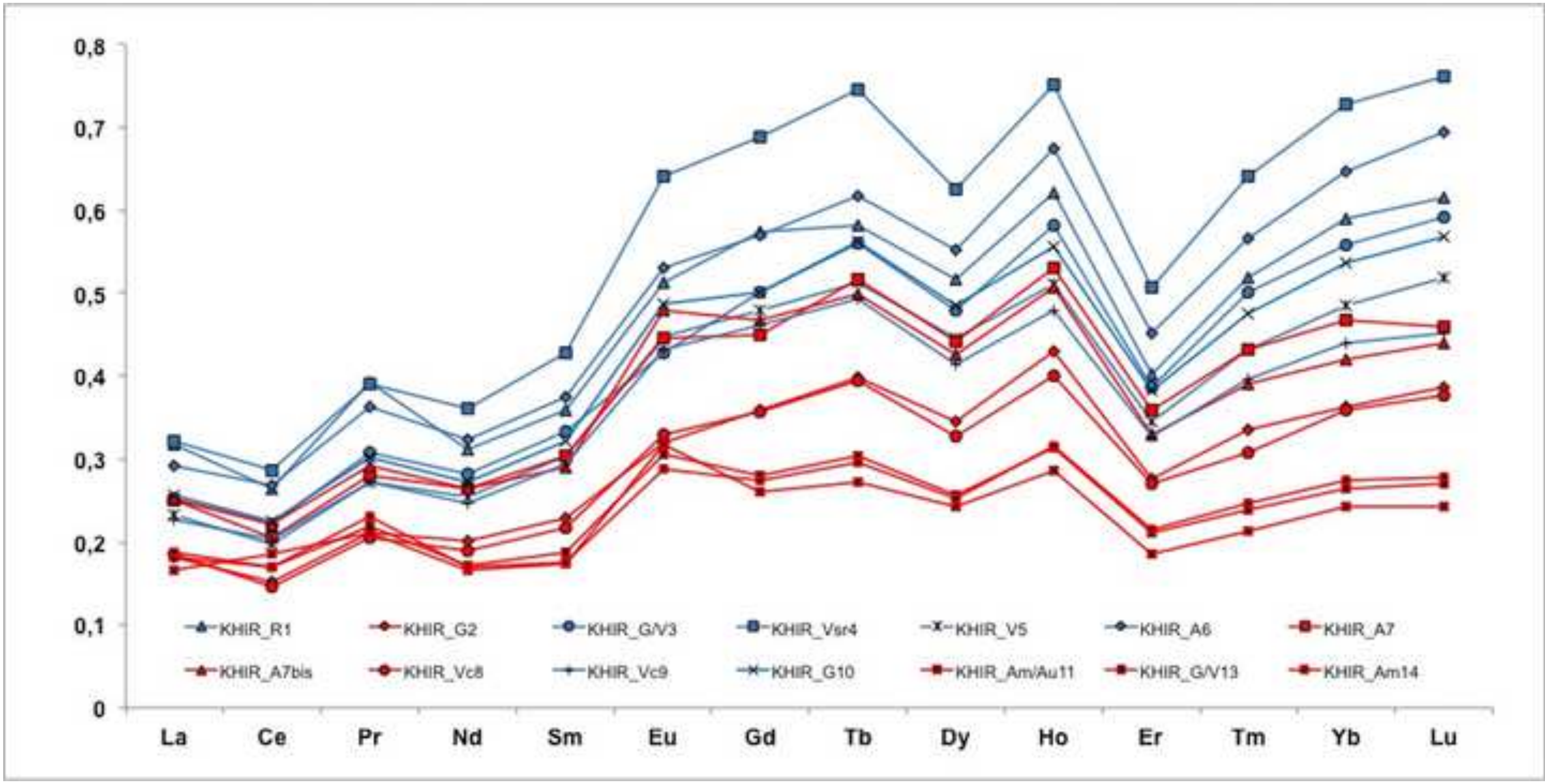

Figure 5

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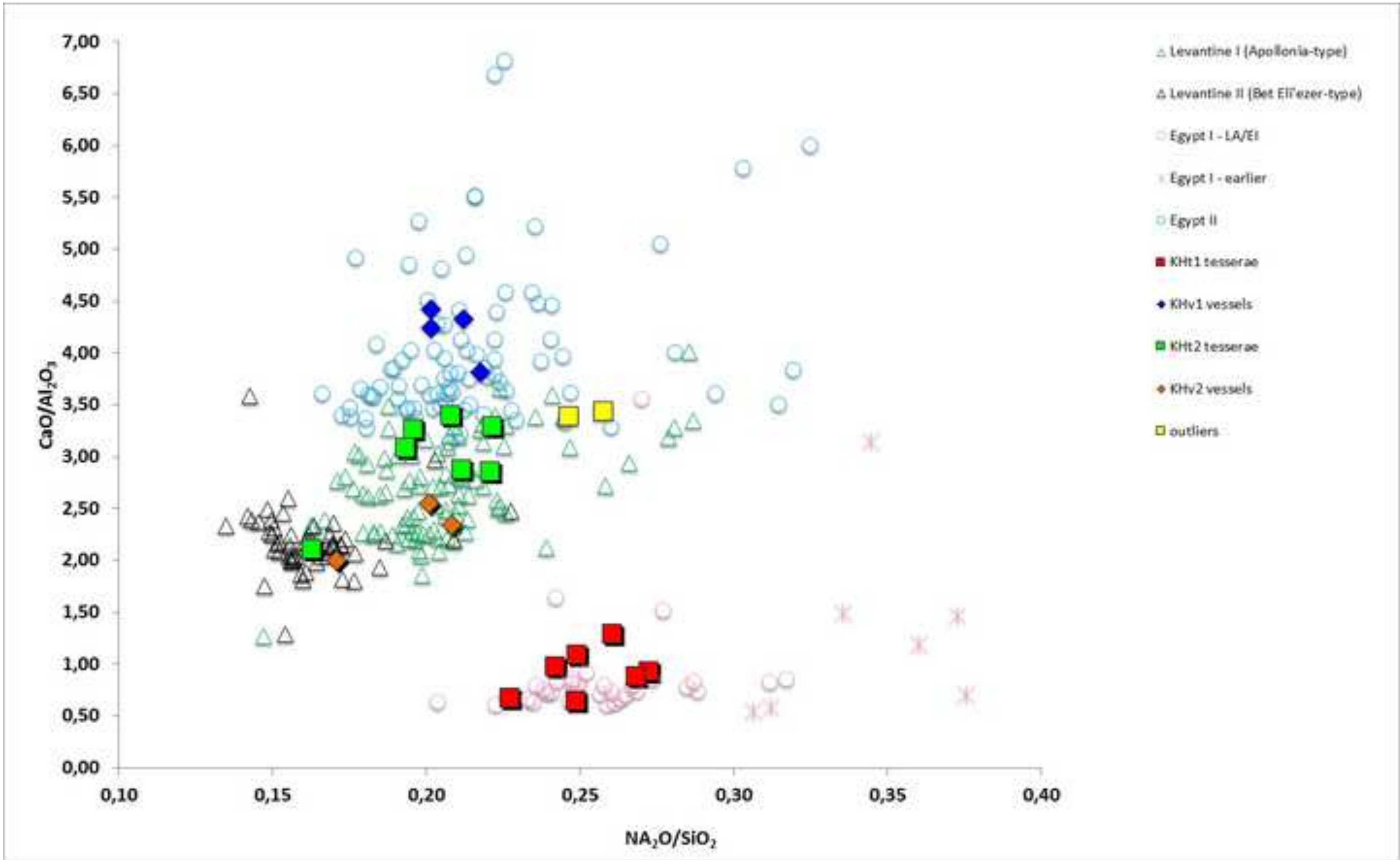

Figure 6

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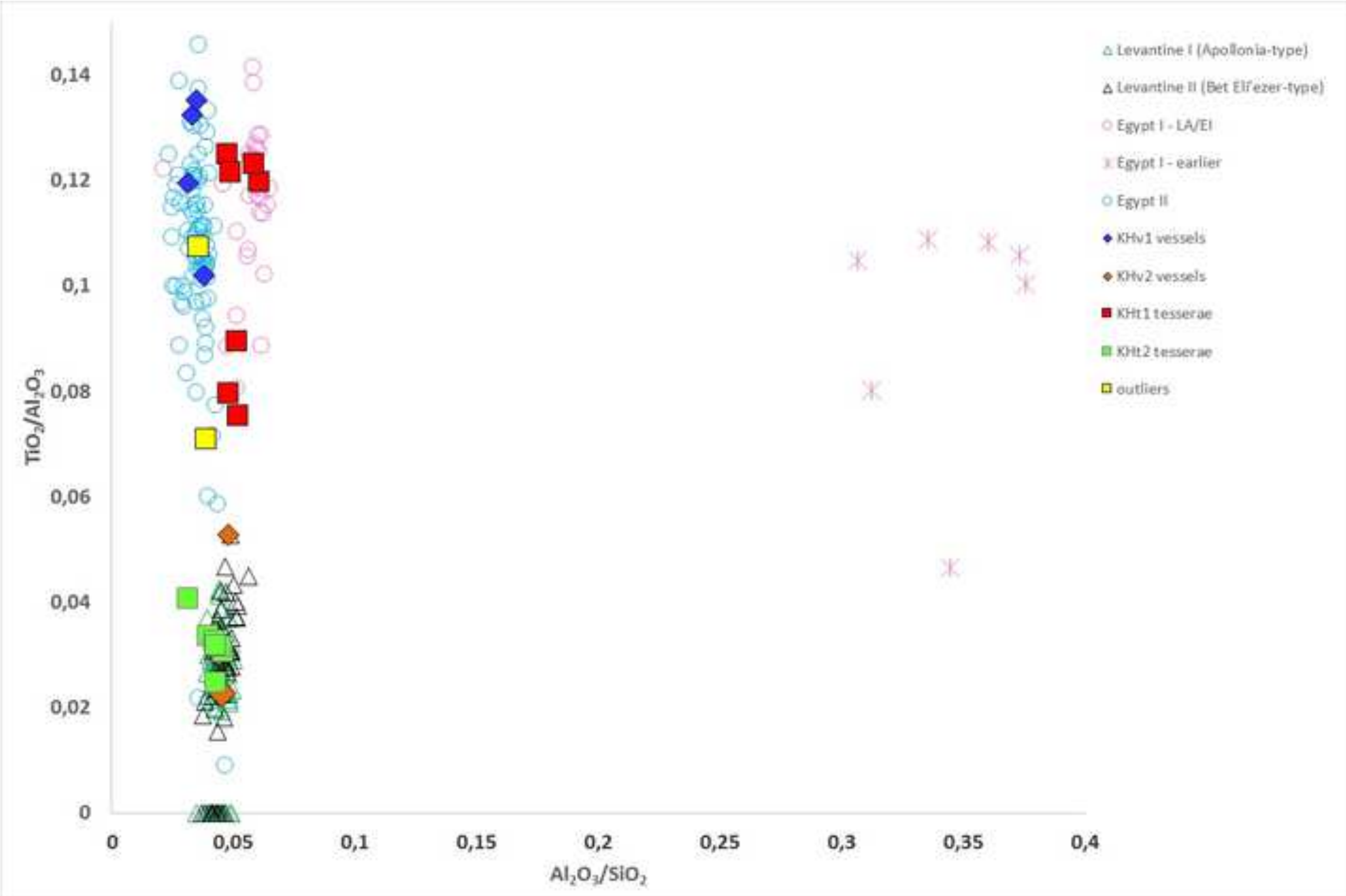

Figure 7

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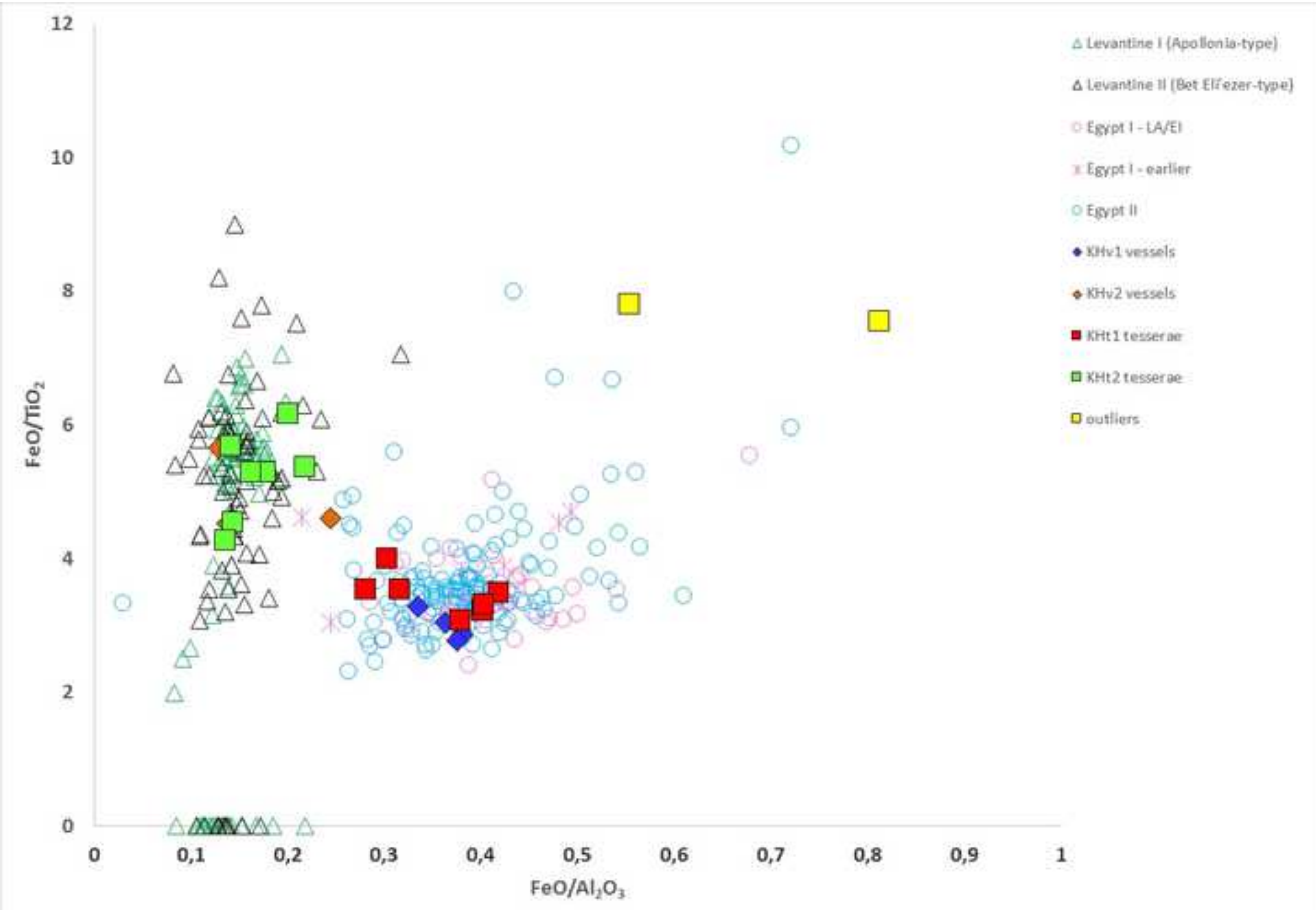

Figure 8

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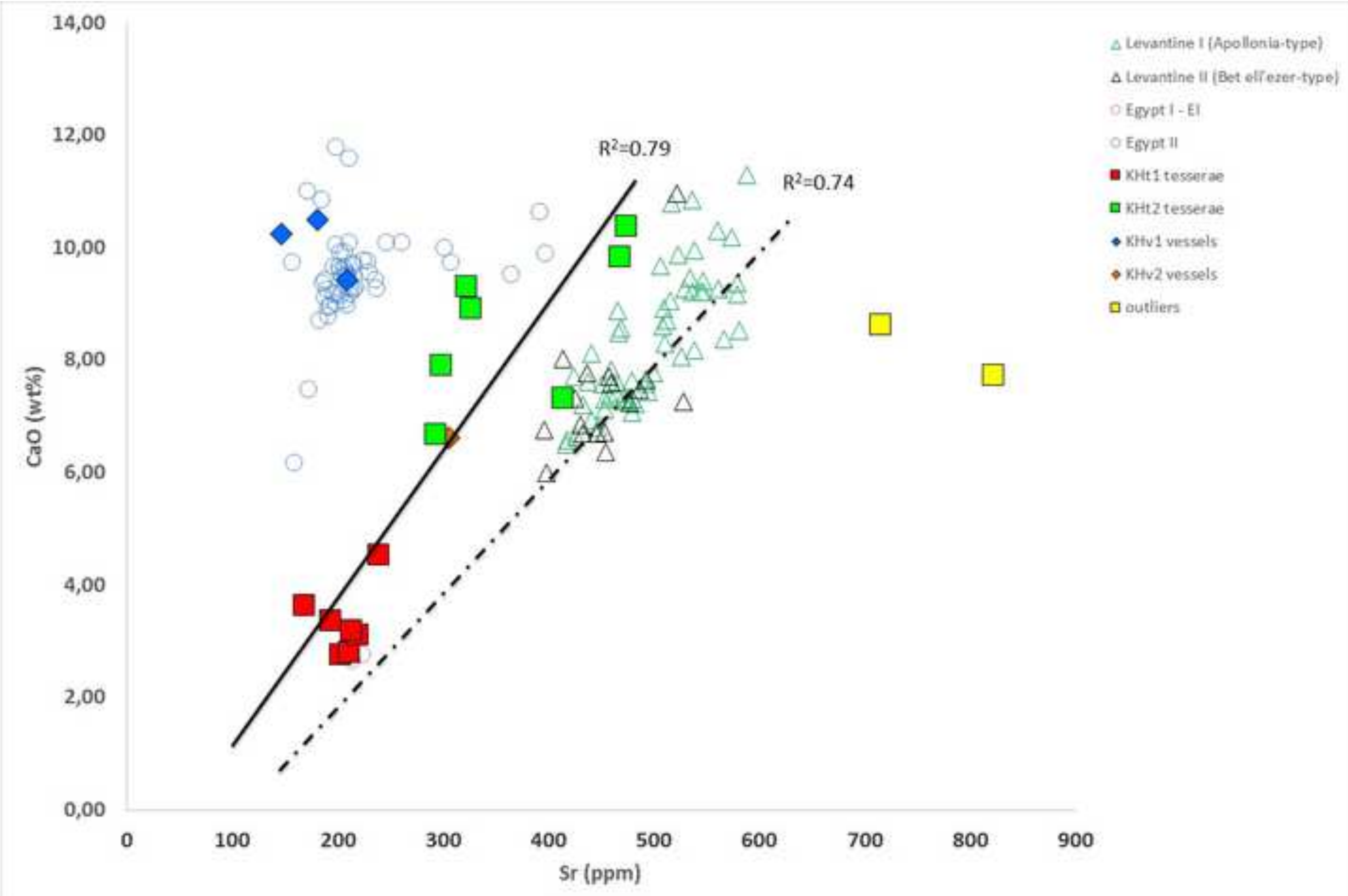
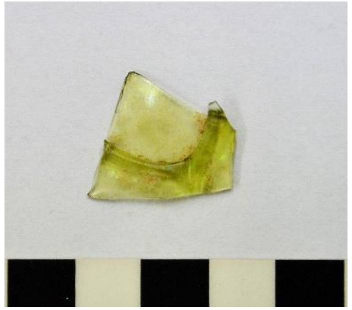
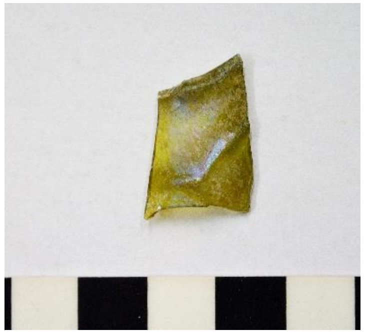


Table 1.a

Sample	Object	Photo	Typology	Datig (by form)	References
KH01	Loop handle with pinched thumb-rest		Cup or cup-shaped oil lamp	end 7th - 8th century	Hadad 2005, pl. 21, n. 398 (first half of 8th century); Gorin-Rosen and Katsnelson 2005, p. 112, n. 40 (8th century); Gorin-Rosen 2007, p. 49, n. 9 (Abassid/Fatimid period); Gorin-Rosen 2008, p.124, n. 16 (Late Byzantine/ Umayyad period); Gorin-Rosen 2010, p. 252, pl. 10.11, n. 4 (without thumb-rest) (Abassid/Fatimid period)
KH02	Wall with trails		Unidentified vessel with bifurcated ribs decoration?	3rd – 8th century	Harden 1936, pl. XVIII, n. 593 (2nd-3rd century); Crowfoot 1957, fig. 94, n. 12 (3rd century); Clairmont 1963, pl. V, n. 189 (2nd-3rd century); Barag 1978, p. 24, fig. 12.50 (late 3rd-4th century); Weinberg and Goldstein 1988, p. 81, fig. 4-39 (2nd-4th century); Dussart 1998, BX.3211c, n. 11 (end 3rd-4th century); Gorin-Rosen 2006, p. 52, n. 27 (late Byzantine-Umayyad period); Gorin-Rosen 2007, p. 107, fig. 15.1 (late Roman-Early Byzantine period); Antonaras 2010, fig. 3 (last on the second row) (mid 3rd-4th century)
KH03	Wall with trails		Unidentified vessel with bifurcated ribs decoration?	3rd – 8th century	Harden 1936, pl. XVIII, n. 593 (2nd-3rd century); Crowfoot 1957, p. 410, n. 94.12 (4th century); Clairmont 1963, pl. V, n. 189 (2nd-3rd century); Barag 1978, p. 24, fig. 12.50 (late 3rd-4th century); Weinberg and Goldstein 1988, p. 81, fig. 4-39 (2nd-4th century); Dussart 1998, BX.3211c, n. 11 (end 3rd-4th century); Gorin-Rosen 2006, p. 52, n. 27 (late Byzantine-Umayyad period); Gorin-Rosen 2007, p. 107, fig. 15.1 (late Roman-Early Byzantine period); Antonaras 2010, fig. 3 (last on the second row) (mid 3rd-4th century)

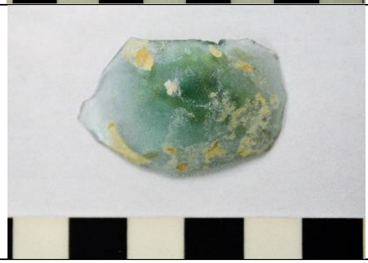
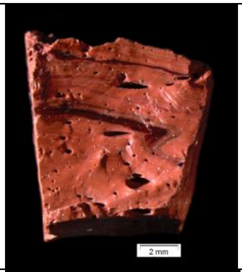
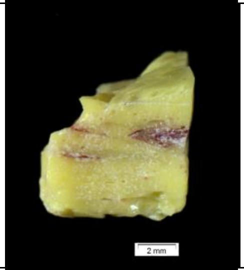
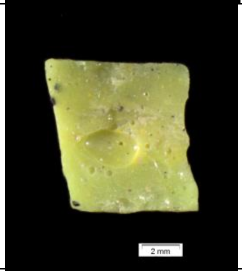
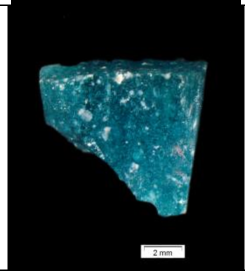
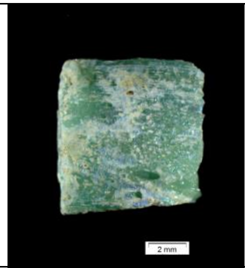
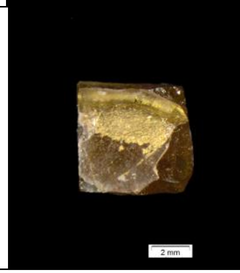
KH04	Straight rim with wall folded toward inside		Small bottle	Second half 4th – first half 8th century	Dussard 1998, BX.3244, n. 29 (second half 4th-6th century); Hadad 2005, pl. 7, n. 126 (first half 8th century)
KH05	Small infolded rim		Small bottle	7th – 8th century	Katsnelson 1999, p. 72, fig. 3, n. 3 (late Byzantine); Dussart 1998, BXIII.1931bI, n. 19 (first half 8th century); Gorin-Rosen 2010, p.234, pl. 10.6, n. 3 (Umayyad period)
KH06	Slightly concave bottom		Globular bottle	5th – 8th century	Katsnelson 1999, p. 72, fig. 3, n. 14 (5th-6th century); Foy 2012, pl. 18, n. 36 (8th century)
KH07	Central fragment of bottom		Unidentified vessel	Undated	Hadad 2005, pl. 11, n. 208 (Umayyad period)?

Table 1.b

Sample	Visible colour	NCS	OM photo
R1	Red	S 5040-Y80R	
G2	Yellow with red strips	S 2040-G90Y	
G/V3	Greenish yellow	S 2040-G80Y	
Vsr4	Green with red strips	S 5030-G30Y	

V5	Green	S 4030-G30Y		
A6	Turquoise	S 5040-B80G		
A7	Turquoise	S 4040-B20G		
A7bis	Turquoise	S 4055-B40G		

Vc8	Light green	S 3040-G	
Vc9	Light Green	S 3065-G40Y	
Ga10	Greyish weak turquoise	S 1510-G	
Am/Au11	Amber with golden leaf	S 4050-Y10R	

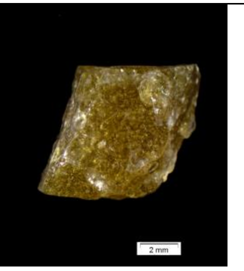
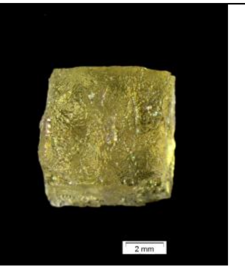
Am12	Amber	S 6030-Y20R	
G/V13	Greenish yellow	S 2050-Y	
Am14	Amber	S 2060-Y	
A15	Weak turquoise	S 0515-B20G	

Table 2a

Sample	Typology	Colour	Opacity	Compositional category	Group	Value	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	Cr_2O_3	MnO	FeO	CoO	CuO	SnO_2	Sb_2O_3	PbO	Total
KH01	Vessel	Weak green	Translucent	Egypt II	KHv1	**Mean**	14.19	0.52	2.32	70.35	0.09	0.1	1.53	0.23	10.25	0.31	0.01	0.02	0.88	nd	0.01	0.01	nd	0.05	100.86
						StDev	0.50	0.02	0.13	0.31	0.02	0.04	0.02	0.13	0.05	0.02	0.01	0.03	0.04	-	0.01	0.01	-	0.02	
KH02	Vessel	Weak green	Translucent	Egypt II	KHv1	**Mean**	15.09	0.68	2.63	69.42	0.1	0.06	1.32	0.37	10.01	0.27	0.01	0.07	0.88	nd	nd	0.02	nd	0.08	101.01
						StDev	0.30	0.02	0.09	0.37	0.032	0.02	0.02	0.05	0.11	0.01	0.01	0.01	0.04	-	-	0.01	-	0.07	
KH03	Vessel	Weak green	Translucent	Egypt II	KHv1	**Mean**	14.36	0.5	2.22	71.26	0.08	0.19	1.37	0.28	9.43	0.27	0.01	0.02	0.81	nd	0.01	0.03	nd	0.04	100.87
						StDev	0.37	0.02	0.15	0.42	0.02	0.03	0.03	0.04	0.11	0.03	0.01	0.01	0.01	-	0.01	0.03	-	0.05	
KH04	Vessel	Weak olive green	Translucent	Levantine I Apollonia-type	KHv2	**Mean**	14.29	0.72	3.41	71.17	0.12	0.07	0.95	0.53	8.71	0.18	nd	0.04	0.83	0.01	0.01	nd	nd	0.05	101.09
						StDev	0.31	0.02	0.18	0.43	0.02	0.03	0.04	0.05	0.11	0.01	-	0.01	0.04	0.01	0.01	-	-	0.04	
KH05	Vessel	Weak turquoise	Translucent	Egypt II	KHv1	**Mean**	14.84	0.6	2.43	69.95	0.07	0.13	1.58	0.3	10.5	0.33	0.02	0.03	0.91	0.01	0.01	0.01	nd	0.04	101.76
						StDev	0.34	0.01	0.09	0.43	0.01	0.02	0.04	0.06	0.11	0.02	0.01	0.01	0.03	0.01	0.01	0.01	-	0.04	
KH06	Vessel	Weak turquoise	Translucent	Levantine II Bet Eli'ezer-type	KHv2	**Mean**	12.89	0.54	3.32	75.44	0.07	0.04	1.05	0.5	6.63	0.1	0.02	0.02	0.46	0.01	0.01	0.01	0.01	0.03	101.15
						StDev	0.18	0.01	0.16	0.35	0.02	0.03	0.02	0.03	0.07	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.03	
KH07	Vessel	Weak turquoise	Translucent	Levantine I Apollonia-type	KHv2	**Mean**	15.06	0.5	3.28	72.27	0.06	0.11	1.27	0.62	7.7	0.07	0.01	0.02	0.42	0.01	0.01	nd	nd	0.04	101.46
						StDev	0.31	0.02	0.11	0.54	0.02	0.02	0.02	0.08	0.05	0.01	0.01	0.01	0.03	0.01	0.01	-	-	0.04	
R1	Tessera	Red	Opaque	Egypt I	KHt1	**Mean**	16.86	0.88	4.11	67.83	0.08	0.04	1.29	0.47	2.66	0.49	0.02	0.04	1.72	0.01	2.58	0.37	nd	0.85	100.3
						StDev	0.40	0.03	0.19	1.56	0.02	0.02	0.04	0.05	0.05	0.02	0.01	0.01	0.33	0.01	0.29	0.25	-	0.26	
G2	Tessera	Yellow	Opaque	Levantine I Apollonia-type	KHt2	**Mean**	11.1	0.61	1.98	50.24	0.06	0.05	0.8	0.53	5.65	0.07	0.01	0.03	0.35	0.01	0.39	2.3	nd	24.87	99.03
						StDev	0.25	0.03	0.09	0.91	0.02	0.03	0.04	0.09	0.08	0.01	0.02	0.01	0.02	0.01	0.02	0.27	-	0.93	
G/V3	Tessera	Greenish yellow	Opaque	Egypt I	KHt1	**Mean**	13.84	0.7	2.64	55.61	0.09	0.06	1.17	0.37	2.86	0.33	0.01	0.72	1.06	nd	0.01	1.99	nd	17.94	99.41

G/V3	Tessera	Greenish yellow	Opaque	Egypt I	KHt1	StDev	0.44	0.03	0.12	1.54	0.02	0.01	0.04	0.05	0.11	0.02	0.01	0.06	0.04	-	0.01	0.40	-	1.77	
Vsr4	Tessera	Green	Opaque	Egypt I	KHt1	**Mean**	14.47	0.77	3.71	63.67	0.08	0.05	1.21	0.47	2.48	0.46	0.02	0.11	1.41	nd	1.82	1.16	nd	8.63	100.51
						StDev	0.34	0.01	0.18	0.93	0.01	0.03	0.04	0.06	0.07	0.02	0.02	0.01	0.04	-	0.07	0.08	-	0.61	
V5	Tessera	Green	Opaque	Egypt I	KHt1	**Mean**	16.36	0.58	2.87	60.05	0.09	0.1	1.28	0.49	2.67	0.23	0.01	0.04	0.81	0.01	1.47	0.82	0.04	10.89	98.8
						StDev	0.28	0.02	0.14	0.85	0.02	0.03	0.03	0.05	0.04	0.01	0.01	0.01	0.01	0.01	0.04	0.06	0.01	0.25	
A6	Tessera	Weak turquoise	Opaque	Egypt I	KHt1	**Mean**	16.73	0.72	3.36	69.13	0.58	0.07	1.48	0.44	3.28	0.41	0.01	0.56	1.35	0.01	2.42	0.16	nd	0.53	101.23
						StDev	0.41	0.02	0.16	1.15	0.12	0.02	0.04	0.07	0.09	0.02	0.01	0.02	0.03	0.02	0.05	0.05	-	0.07	
A7	Tessera	Weak turquoise	Opaque	Levantine I Apollonia-type	KHt2	**Mean**	13.97	0.71	2.82	67.19	0.35	0.07	0.99	1.19	9.59	0.09	0.01	0.34	0.57	0.03	1.77	0.1	nd	0.4	100.16
						StDev	0.63	0.05	0.15	0.52	0.03	0.02	0.04	0.13	0.18	0.01	0.01	0.02	0.01	0.04	0.06	0.03	-	0.07	
A7bis	Tessera	Weak turquoise	Opaque	Levantine I Apollonia-type	KHt2	**Mean**	13.26	0.7	3.11	67.78	0.2	0.13	1.1	0.74	10.14	0.1	0.01	0.05	0.5	0.05	1.7	0.12	nd	0.26	99.9
						StDev	0.38	0.01	0.08	0.52	0.01	0.05	0.03	0.06	0.08	0.01	0.01	0.01	0.02	0.06	0.10	0.02	-	0.06	
Sample	**Typology**	**Colour**	**Opacity**	**Compositional category**	**Group**	**Value**	**Na_2O**	**MgO**	**Al_2O_3**	**SiO_2**	**P_2O_5**	**SO_3**	**Cl**	**K_2O**	**CaO**	**TiO_2**	**Cr_2O_3**	**MnO**	**FeO**	**CoO**	**CuO**	**SnO_2**	**Sb_2O_3**	**PbO**	**Total**
Vc8	Tessera	Green	Opaque	Levantine I Apollonia-type	KHt2	**Mean**	12.88	0.73	1.83	58.18	0.24	0.12	0.95	0.71	6.00	0.07	nd	0.37	0.4	0.07	0.7	1.47	nd	14.56	99.23
						StDev	0.21	0.02	0.10	0.46	0.02	0.04	0.04	0.07	0.05	0.01	-	0.02	0.02	0.08	0.03	0.09	-	0.42	
Vc9	Tessera	Green	Opaque	Egypt I	KHt1	**Mean**	16.27	0.56	3.15	60.66	0.14	0.14	1.41	0.53	2.77	0.24	0.01	0.04	0.95	0.09	1.12	0.81	nd	11.53	100.34
						StDev	0.32	0.02	0.12	0.44	0.01	0.03	0.03	0.06	0.05	0.02	0.01	0.01	0.01	0.10	0.04	0.07	-	0.41	
Ga10	Tessera	Greyish-weak turquoise	Opaque	Egypt I	KHt1	**Mean**	18.18	0.68	3.58	69.81	0.9	0.15	1.59	0.66	4.6	0.32	0.01	0.04	1.13	0.11	0.01	0.01	0.01	0.04	101.71
						StDev	0.37	0.02	0.13	0.91	0.45	0.02	0.05	0.06	0.33	0.02	0.01	0.01	0.03	0.12	0.01	0.01	0.01	0.04	
Am/Au11	Tessera	Weak brown (traces of gold leaf)	Translucent	Levantine II Bet Eli'ezer-type	KHt2	**Mean**	12.09	0.49	3.17	74.32	0.05	0.11	0.95	0.56	6.68	0.1	0.01	1.87	0.43	0.13	0.01	0.01	nd	0.03	100.9
						StDev	0.60	0.02	0.08	0.32	0.02	0.02	0.02	0.05	0.06	0.01	0.01	0.01	0.02	0.14	0.01	0.01	-	0.03	
Am12	Tessera	Weak brown	Translucent		outlier	**Mean**	16.28	1.26	2.55	66.07	0.1	0.28	1.13	0.59	8.63	0.18	nd	0.1	1.41	0.15	nd	0.01	0.01	0.04	98.65

Am12	Tessera	Weak brown	Translucent		outlier	StDev	0.32	0.02	0.12	0.83	0.02	0.03	0.04	0.04	0.08	0.01	-	0.03	0.04	0.16	-	0.01	0.01	0.04	
G/V13	Tessera	Greenish yellow	Translucent	Levantine I Apollonia-type	KHt2	**Mean**	13.71	0.69	3.01	71.01	0.17	0.06	1.18	0.96	9.3	0.07	0.01	0.02	0.42	0.17	0.02	nd	nd	0.05	100.69
						StDev	0.53	0.01	0.18	0.52	0.02	0.02	0.03	0.08	0.08	0.01	0.01	0.01	0.01	0.18	0.01	-	-	0.04	
Am14	Tessera	Weak brown	Translucent	Levantine I Apollonia-type	KHt2	**Mean**	14.62	0.74	3.11	69.1	0.08	0.19	1.06	0.72	8.93	0.1	0.01	2.58	0.45	0.19	nd	0.02	0.01	0.02	101.72
						StDev	0.46	0.02	0.08	0.42	0.02	0.03	0.02	0.04	0.08	0.02	0.01	0.01	0.02	0.20	-	0.02	0.01	0.03	
A15	Tessera	Weak turquoise	Translucent		outlier	**Mean**	16.28	2.23	2.26	63.17	0.37	0.31	0.7	1.68	7.74	0.24	0.01	nd	1.83	0.21	0.01	0.01	nd	0.02	96.85
						StDev	0.50	0.02	0.13	0.31	0.02	0.04	0.02	0.13	0.05	0.02	0.01	-	0.04	0.22	0.01	0.01	-	0.02	

Table 2b

Table 2.b

Sample	Typology	Colour	Opacity	Compositional category	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	Cr_2O_3	FeO	CoO	Sb_2O_3
R1	Tessera	Red	Opaque	Egypt I	KHt1	17.48	0.91	4.26	70.32	0.09	0.04	1.34	0.49	2.75	0.51	0.02	1.78	0.01	-
G2	Tessera	Yellow	Opaque	Levantine I Apollonia-type	KHt2	15.53	0.85	2.77	70.32	0.08	0.07	1.12	0.74	7.91	0.09	0.02	0.49	0.01	-
G/V3	Tessera	Greenish yellow	Opaque	Egypt I	KHt1	17.58	0.89	3.35	70.63	0.12	0.07	1.49	0.47	3.63	0.42	0.01	1.35	-	-
Vsr4	Tessera	Green	Opaque	Egypt I	KHt1	16.29	0.87	4.18	71.71	0.09	0.05	1.36	0.52	2.80	0.51	0.02	1.58	-	-
V5	Tessera	Green	Opaque	Egypt I	KHt1	19.12	0.68	3.35	70.17	0.10	0.11	1.49	0.57	3.12	0.27	0.01	0.94	0.02	0.04
A6	Tessera	Weak turquoise	Opaque	Egypt I	KHt1	17.15	0.74	3.44	70.85	0.59	0.08	1.52	0.45	3.36	0.42	0.01	1.39	-	-
A7	Tessera	Weak turquoise	Opaque	Levantine I Apollonia-type	KHt2	14.32	0.73	2.89	68.88	0.36	0.07	1.02	1.22	9.83	0.09	0.01	0.58	0.01	-
A7bis	Tessera	Weak turquoise	Opaque	Levantine I Apollonia-type	KHt2	13.56	0.71	3.18	69.33	0.21	0.13	1.12	0.75	10.37	0.10	0.01	0.52	0.01	-
Vc8	Tessera	Green	Opaque	Levantine I Apollonia-type	KHt2	15.68	0.89	2.22	70.84	0.29	0.14	1.16	0.87	7.31	0.09	-	0.49	0.02	-
Vc9	Tessera	Green	Opaque	Egypt I	KHt1	18.74	0.64	3.63	69.86	0.16	0.16	1.63	0.61	3.19	0.27	0.01	1.10	0.01	-
Ga10	Tessera	Greyish-weak turquoise	Opaque	Egypt I	KHt1	17.89	0.67	3.52	68.70	0.89	0.15	1.56	0.65	4.53	0.31	0.01	1.11	-	0.01

Table 3

Sample	Typology	Colour	Opacity	Compositional category	Group	Sc	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Sn	Sb	Ba	La
KH01	Vessel	Weak green	Translucent	Egypt II	KHv1	5.59	1405.00	17.22	18.21	2.46	5.44	2.41	17.09	2.41	3.64	146.85	6.31	129.05	3.21	0.37	0.09	124.48	7.45
KH02	Vessel	Weak green	Translucent	Egypt II	KHv1																		
KH03	Vessel	Weak green	Translucent	Egypt II	KHv1	6.09	1271.25	17.40	23.51	5.12	7.11	33.95	28.33	2.85	4.55	209.20	6.16	143.98	2.97	10.83	1.55	154.20	7.58
KH04	Vessel	Weak green	Translucent	Levantine I Apollonia type	KHv2	6.54	939.33	16.82	17.01	2.39	6.05	36.65	21.01	2.88	8.46	321.93	7.34	63.95	2.22	4.32	1.56	186.25	8.25
KH05	Vessel	Weak turquoise	Translucent	Egypt II	KHv1	6.47	1665.50	21.09	27.23	2.67	6.48	2.86	15.96	2.77	4.38	180.73	7.92	258.40	4.01	0.43	0.08	150.02	8.74
KH06	Vessel	Weak turquoise	Translucent	Levantine II Bet Eli'ezer-type	KHv2	5.62	470.08	9.18	13.72	1.43	4.19	2.75	7.40	3.31	9.43	305.47	4.95	35.30	1.53	0.60	0.04	193.52	6.16
KH07	Vessel	Weak turquoise	Translucent	Levantine I Apollonia type	KHv2																		
R1	Tessera	Red	Opaque	Egypt I	KHt1	9.92	2716.20	38.10	52.15	7.57	32.19	12178.00	1528.20	4.45	8.40	203.02	9.80	150.50	4.26	1002.86	23.40	213.18	10.24
G2	Tessera	Yellow	Opaque	Levantine I Apollonia type	KHt2	4.59	400.63	6.83	9.84	1.90	8.20	2355.67	154.18	2.31	5.78	298.18	6.04	41.85	1.27	16715.00	194.38	163.83	5.87
G/V3	Tessera	Greenish yellow	Opaque	Egypt I	KHt1	7.58	1872.33	26.13	36.94	4.71	10.19	192.32	56.87	3.53	5.69	168.15	7.93	141.52	3.40	17000.00	82.03	217.53	8.09
Vsr4	Tessera	Green	Opaque	Egypt I	KHt1	9.14	2482.17	34.62	53.91	6.56	24.67	11116.67	877.35	4.63	7.42	211.58	9.81	176.40	4.47	7881.00	57.85	206.17	10.41
V5	Tessera	Green	Opaque	Egypt I	KHt1	8.64	1387.67	21.53	33.89	5.55	17.45	8308.17	1003.12	3.30	7.26	219.28	6.91	94.06	2.72	5049.17	68.00	157.40	7.49
A6	Tessera	Weak turquoise	Opaque	Egypt I	KHt1	8.42	2253.83	29.82	45.27	6.96	28.69	14640.00	996.22	4.12	6.17	193.52	8.62	144.47	4.20	1034.63	21.54	245.62	9.41
A7	Tessera	Weak turquoise	Opaque	Levantine I Apollonia type	KHt2	6.00	525.60	13.26	17.21	10.57	20.81	9692.00	37.63	3.00	12.04	467.55	7.65	54.06	1.73	606.50	22.43	238.93	8.06
A7bis	Tessera	Weak turquoise	Opaque	Levantine I Apollonia type	KHt2	6.73	480.70	9.72	12.54	18.07	39.50	8780.83	47.77	3.16	10.27	474.43	7.55	47.01	1.61	662.00	7.15	231.73	8.17
Vc8	Tessera	Green	Opaque	Levantine I Apollonia type	KHt2	5.66	434.85	11.92	12.54	8.74	14.08	4226.33	364.68	2.31	5.30	413.30	5.77	49.47	1.34	10906.50	188.50	188.37	6.00
Vc9	Tessera	Green	Opaque	Egypt I	KHt1	7.20	1363.83	22.23	32.44	5.49	16.42	6778.50	658.53	3.53	7.53	213.03	6.57	85.21	2.75	5776.50	95.68	173.15	7.32
Ga10	Tessera	Greyish-weak	Opaque	Egypt I	KHt1	7.95	1649.33	24.87	37.92	3.59	7.19	14.61	27.59	3.59	8.36	238.93	7.71	111.60	3.18	2.30	0.09	182.58	8.28
Am/Au11	Tessera	Weak brown (traces of gold leaf)	Translucent	Levantine II Bet Eli'ezer-type	KHt2	9.79	398.00	8.23	14.28	1.31	4.05	2.75	9.42	3.05	10.04	293.05	4.20	28.33	1.28	0.61	0.03	180.72	5.36
Am12	Tessera	Weak brown	Translucent		outlier	9.70	852.80	39.11	15.00	11.94	15.85	56.85	31.07	3.29	6.21	715.30	9.93	86.55	2.73	5.90	142.27	394.50	11.96
G/V13	Tessera	Greenish yellow	Translucent	Levantine I Apollonia type	KHt2	8.15	372.84	9.33	12.32	5.95	4.70	39.21	18.91	2.76	12.19	322.72	5.20	29.77	1.06	7.89	5.14	192.86	5.87
Am14	Tessera	Weak brown	Translucent	Levantine I Apollonia type	KHt2	8.08	427.57	10.10	10.70	1.33	3.53	4.53	9.57	2.71	10.75	326.13	5.35	34.07	1.15	0.71	0.24	186.73	6.06
A15	Tessera	Weak turquoise	Translucent		outlier	9.16	1273.33	46.53	22.85	26.96	50.57	59.55	68.50	3.58	7.82	822.28	11.02	120.83	3.27	1.63	15.68	410.35	14.56

Sample	Typology	Colour	Opacity	Compositional category	Group	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	Au	Pb	Th
KH01	Vessel	Weak green	Translucent	Egypt II	KHv1	13.09	1.73	5.86	1.14	0.32	1.10	0.19	1.06	0.29	0.64	0.11	0.64	0.13	3.05	0.24	0.00	3.37	1.48
KH02	Vessel	Weak green	Translucent	Egypt II	KHv1																		
KH03	Vessel	Weak green	Translucent	Egypt II	KHv1	14.28	1.73	6.08	1.25	0.35	1.13	0.21	1.11	0.28	0.63	0.12	0.65	0.13	3.31	0.22	0.01	320.00	1.62
KH04	Vessel	Weak green	Translucent	Levantine I Apollonia type	KHv2	12.94	1.90	5.52	1.10	0.31	0.98	0.19	0.95	0.24	0.52	0.09	0.58	0.10	1.60	0.15	0.00	128.32	1.17
KH05	Vessel	Weak turquoise	Translucent	Egypt II	KHv1	15.32	1.95	7.24	1.51	0.33	1.26	0.27	1.38	0.34	0.82	0.15	0.88	0.19	6.15	0.30	0.00	4.18	2.15

KH06	Vessel	Weak turquoise	Translucent	Levantine II Bet Eli'ezer-type	KHv2	12.88	1.46	5.04	1.00	0.31	0.84	0.17	0.84	0.21	0.46	0.08	0.42	0.08	0.88	0.10	0.00	6.20	0.81
KH07	Vessel	Weak turquoise	Translucent	Levantine I Apollonia type	KHv2																		
R1	Tessera	Red	Opaque	Egypt I	KHt1	17.36	2.47	8.08	1.68	0.49	1.61	0.29	1.50	0.39	0.84	0.16	0.88	0.17	3.54	0.30	0.03	4306.40	1.87
G2	Tessera	Yellow	Opaque	Levantine I Apollonia type	KHt2	9.96	1.33	5.21	1.08	0.30	1.01	0.20	1.00	0.27	0.58	0.10	0.54	0.10	1.08	0.11	0.08	188216.67	0.91
G/V3	Tessera	Greenish yellow	Opaque	Egypt I	KHt1	14.53	1.94	7.29	1.57	0.41	1.40	0.28	1.39	0.36	0.81	0.15	0.84	0.16	3.54	0.28	0.06	165866.67	1.77
Vsr4	Tessera	Green	Opaque	Egypt I	KHt1	18.83	2.46	9.37	2.01	0.61	1.93	0.37	1.81	0.47	1.07	0.19	1.09	0.21	4.51	0.37	0.65	69925.00	2.30
V5	Tessera	Green	Opaque	Egypt I	KHt1	12.88	1.72	6.61	1.43	0.43	1.34	0.26	1.29	0.32	0.73	0.13	0.73	0.14	2.50	0.22	0.43	104133.33	1.43
A6	Tessera	Weak turquoise	Opaque	Egypt I	KHt1	17.61	2.28	8.35	1.76	0.50	1.59	0.31	1.60	0.42	0.95	0.17	0.97	0.19	3.77	0.32	0.78	4667.00	2.07
A7	Tessera	Weak turquoise	Opaque	Levantine I Apollonia type	KHt2	13.44	1.76	6.84	1.43	0.42	1.26	0.26	1.28	0.33	0.75	0.13	0.70	0.12	1.44	0.14	0.37	3065.00	1.21
A7bis	Tessera	Weak turquoise	Opaque	Levantine I Apollonia type	KHt2	14.55	1.84	6.82	1.36	0.45	1.31	0.25	1.24	0.31	0.69	0.12	0.63	0.12	1.20	0.12	0.20	2235.33	1.08
Vc8	Tessera	Green	Opaque	Levantine I Apollonia type	KHt2	9.54	1.30	4.91	1.02	0.31	1.00	0.20	0.95	0.25	0.57	0.09	0.54	0.10	1.29	0.11	0.66	139966.67	1.01
Vc9	Tessera	Green	Opaque	Egypt I	KHt1	13.28	1.71	6.39	1.38	0.41	1.29	0.25	1.20	0.30	0.69	0.12	0.66	0.12	2.19	0.22	0.39	102541.67	1.36
Ga10	Tessera	Greyish-weak turquoise	Opaque	Egypt I	KHt1	14.76	1.90	7.03	1.51	0.46	1.40	0.28	1.40	0.35	0.81	0.14	0.81	0.15	2.90	0.26	0.00	30.47	1.64
Am/Au11	Tessera	Weak brown (traces of gold leaf)	Translucent	Levantine II Bet Eli'ezer-type	KHt2	12.14	1.32	4.29	0.82	0.30	0.73	0.14	0.70	0.18	0.39	0.06	0.36	0.07	0.70	0.08	0.00	6.91	0.68
Am12	Tessera	Weak brown	Translucent		outlier	16.19	2.55	9.09	1.85	0.55	1.77	0.34	1.68	0.44	1.01	0.17	0.92	0.17	2.12	0.20	0.00	91.99	1.60
G/V13	Tessera	Greenish yellow	Translucent	Levantine I Apollonia type	KHt2	11.14	1.38	4.41	0.88	0.29	0.78	0.15	0.74	0.19	0.44	0.07	0.40	0.07	0.75	0.08	0.00	113.60	0.66
Am14	Tessera	Weak brown	Translucent	Levantine I Apollonia type	KHt2	11.14	1.45	4.37	0.82	0.27	0.77	0.15	0.73	0.20	0.45	0.07	0.41	0.08	0.87	0.08	0.00	11.48	0.71
A15	Tessera	Weak turquoise	Translucent		outlier	17.38	2.94	10.72	2.22	0.57	2.12	0.40	2.03	0.52	1.21	0.21	1.16	0.21	2.85	0.25	0.00	26.14	1.96

Captions

Figures

Fig. 1.a) Location of the *qasr* of Khirbat al-Mafjar; b) area of the *qasr* where the glass findings were unearthed.

Fig. 2. Drawings of the analysed vessel fragments.

Fig. 3. K_2O versus MgO bi-plot (for the opaque tesserae the reduced wt% contents are used). Samples belonging to the same group (see paragraph 5.Discussion) are shown by using the same shape and colour.

Fig. 4. a) Trace elements patterns and b) REE patterns of the vessels analysed by LA–ICP–MS. A blue line is used KHv1 vessels, whilst a red line identifies the KHv2 ones. KH02 and KH07 are not reported as LA-ICP-MS analyses did not provide proper results for these samples; c) trace elements patterns and d) REE patterns of the tesserae analysed by LA–ICP–MS. The blue lines identify the samples belonging to KHt1 group, while the red ones are used to distinguish the KHt2 group.

Fig. 5. CaO/Al_2O_3 versus Na_2O/SiO_2 bi-plot (for the opaque tesserae the reduced wt% contents are used).
Apollonia-type references: Freestone et al. 2000; Tal et al. 2004; Freestone et al. 2008; Phelps et al. 2016; Bet Eli'ezer-type: Freestone et al. 2000; Freestone et al. 2015; Phelps et al. 2016; Egypt I late antique/early Islamic references: Gratuze and Barrandon 1990; Foy et al. 2003; Ceglia et al. 2015; Pheps et al. 2016; earlier Egypt I references: Picon et al. 2008; Egypt II references: Bimson and Freestone 1985; Gratuze and Barrandon 1990; Foy et al. 2003; Freestone et al. 2015; Phelps et al. 2016.

Fig. 6. TiO_2/Al_2O_3 versus Al_2O_3/SiO_2 bi-plot (for the opaque tesserae the reduced wt% contents are used).
Apollonia-type references: Freestone et al. 2000; Tal et al. 2004; Freestone et al. 2008; Phelps et al. 2016; Bet Eli'ezer-type: Freestone et al. 2000; Freestone et al. 2015; Phelps et al. 2016; Egypt I late antique/early Islamic references: Gratuze and Barrandon 1990; Foy et al. 2003; Ceglia et al. 2015; Pheps et al. 2016; earlier Egypt I references: Picon et al. 2008; Egypt II references: Bimson and Freestone 1985; Gratuze and Barrandon 1990; Foy et al. 2003; Freestone et al. 2015; Phelps et al. 2016.

Fig. 7. FeO/TiO_2 versus FeO/Al_2O_3 bi-plot (for the opaque tesserae the reduced wt% contents are used).
Apollonia-type references: Freestone et al. 2000; Tal et al. 2004; Freestone et al. 2008; Phelps et al. 2016; Bet Eli'ezer-type: Freestone et al. 2000; Kato et al. 2009; Freestone et al. 2015; Phelps et al. 2016; Egypt I late antique/early Islamic references: Gratuze and Barrandon 1990; Foy et al. 2003; Kato et al. 2009; Ceglia et al. 2015; Pheps et al. 2016; earlier Egypt I references: Picon et al. 2008; Egypt II references: Bimson and Freestone 1985; Gratuze and Barrandon 1990; Foy et al. 2003; Freestone et al. 2015; Phelps et al. 2016; Kato et al. 2009.

Fig. 8. CaO (wt%) versus Sr (ppm) bi-plot (for the opaque tesserae the reduced wt% contents are used). Solid and dotted line show positive correlation between CaO and Sr contents for samples from this study and from the literature, respectively (Phelps et al. 2016).

Tables

Table 1a. Summary and documentation of the vessel samples selected for the analyses.

Table 1b. Summary and documentation of the analysed tesserae. NCS references are also reported.

Table 2a. Chemical compositions of glassy matrix of vessels and tesserae obtained by EMPA. All data are expressed as percentage concentrations of element oxides (nd is for not detected).

Table 2b. Reduced percentage concentrations of element oxides detected by EMPA, calculated for the opaque tesserae. CuO, SnO_2 and PbO were subtracted, whilst Sb_2O_3 and CoO were not detracted due to their scarce concentration (between 0.00 and 0.01 wt%).

Table 3. Trace element composition of the analysed samples obtained by LA-ICP-MS. All data are expressed in ppm.